A FIELD INVESTIGATION ON A WASTEWATER STABILIZATION POND

BY

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DEPARTMENTS OF CIVIL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY KANPUR

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BY

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to the

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CERTIFICATE

This is to certify that the present work has been done under my supervision and the work has not been submitted else where for a degree.

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CHAPTER - I

INTRODUCTION:

1.1 PROBLEM OF WASTESWATER MANAGEMENT

The disposal of human wastes as well as industrial wastes has always been a serious problem. Since past with the development of urban areas, it has become necessary, from public health and aesthetic considerations, to construct drainage or sewer systems to carry such wastes away from the residential areas. The usual approach had always been to dispose off such wastes in the nearby water course. But receiving bodies of water could handle only limited amounts of waste materials without getting into nuisance conditions. Thus development of effective and economical wastemanagement facilities has become the task of engineers.

The wastewater management primarly includes, reliable and inoffensive collection of waste matters, suitable treatment of wastewaters in the required degree and safe disposal of treated wasterwater into receiving bodies of water or on land. If the treatment is not effective, the collection system will merely shift nuisance from one place to another.

The choice of a wastewater treatment method requires consideration of aspects of hygiene, asthetics and economy. If the final disposal is in a water body, the treatment must be of the degree that the usefulness of the receiving waters is not impaired.

The increasing knowledge of the Chemical and biological reactions involved in treatment processes has been evolving newer and more economical methods based on relevent scientific roots.

1.2 DEVELOPMENT OF STABILIZATION PONDS:

A wastewater stabilization pond is designed and constructed to receive raw or pretreated domestic sewage and some organic industrial wastes; in which Stabilization is achieved by several natural self purification phenomena.

The use of some kinds of ponds and natural excavations for disposal of wastes was begun in prehistoric times and has continued until the present. It is believed that moats that surrounded the castles of the middle ages functioned not only as defensives devices, but also incidentially as stabilization ponds where algae flurished and played the vital role of purifying sewage that invariably entered this body of water, from the community living within these castles.(1) In ancient times in the orient and Europe, Algal growths were encouraged by adding organic wastes in many ponds. The abundence of algae thus obtained were used as food for various types of fish and this used to give a bumper yeild of fish crop. During the past 50 years the purification of sewage in fish ponds has become popular in Germany(2)(3). In America the first stabilization pond was not built as treatment device but this was used to exclude wastewater from intrusion into the places where this would be objectionable.

The early use of Stabilization pond, however, is unrecorded. During the early 1900's it was reported that canning wastes were lagooned in basins used primarly for seepage, settling or holding (4). The purification potential of these ponds was realized thereafter. Gillespic (5) gave the first published description of the ponds of Santa Rosa, California, USA, which were built in 1924. After this there has been a succession of papers describing one or several specific pond installations, and articles considering pond design as a rational basis. Review of these and many other papers on stabilization pond has been published by Fitzgerald & Rohlich (6).

1.3 INDIAN ENVIRONMENT FOR STABILIZATION PONDS:

A large proportion of India's population is living in villages and smaller towns and it has not yet been possible to provide these areas with essential facilities like safewater supply and suitable waste disposal ways. It is now for the Indian Engineers to investigate some practicable, low cost water and waste treatment and disposal methods, keeping in front the existing economic situation in India.

Many investigations in other countries have shown the method of stabilizing domestice wates by retaining it in Shallow pond under plenty of sunshine and high temperature, is quite effective and economical. In view of the high temperatures and abundent sunshine, stabilization pond is likely to be the ideal method of demostic waste treatment for Indian villages and towns. Suitably designed and operated ponds give high degree of treatment efficiency. Such ponds can be constructed easily and quickly at a low initial cost. Maintenance of the ponds is easy and trained or skilled operators are not required to look after them. Except grit removal and screening wastewater does not need any other pretreatment. The effluents from the pond can be utilized for

irrigation, fish culture or can be disposed in natural waterways without detoriating the quality of water. It harvested algae can be utilized as cattle or poultry feed.

The Central Public Health Engineering Research Institute, Nagpur has published a brochure on design construction and operation of waste stablization ponds in India(6). In addition, to relevant details about stablization pond performance, it contains performance data of all most all the existing stablization ponds in India. It has been shown that this method of wastewater treatment is well suited for treatment of domestic wastes from population in the range of 2000 to 50,000. If properly designed stabilization ponds can also accomodate the needs of bigger cities in India.

C H A P T E R -2

2.1 CLASSIFICATION OF STABLIZATION PONDS:

The classification of waste receiving ponds is usually made according to their depths,because the production of oxygen and other biological activities depends largely on the depth of the pond. The ponds are of three types, aerobic,facultative an anaerobic.

2.1.1 AEROBIC PONDS:

Such ponds are also named high rate ponds, in these oxidation and photosynthesis are balanced to give complete aerobic stablization of the waste. Excess production of algae can be reclaimed by harvesting. The Algae use solar energy for cell synthesis, utilizing CO_2 as a carbon source and ammonia as a nitrogensource and librate molecular oxygen. Since algae growing in the ponds are directly proportional to the concentration of solar energy, penetration of light is required which restricts pond depth. Oswald(7) has given wide description about these ponds.

2.1.2 ANAEROBIC PONDS:

Anaerobic ponds are usually designed with a depth of 8 to 12 feet. Oswald(8) has suggested a length to width ratio of 4:1. Parker et al (9) have given sufficient information about this type of ponds.

Due to large depth the surface area of the ponds to relatively smaller. Moreover the ponds are capable of taking high organic loadings. Anaerobic formentation processes predominate in such ponds organic matter is degraded anaerobically.

FACULTATIVE PONDS:

In this type of ponds,anaerobic fermentation, aerobic oxidation, and photosynthetic reduction processes occur at varying rates. Most of the stabilization ponds constructed in the fields operate under facultative conditions. The organic waste is stablized both aerobically and anaerobically. Furthermore the growth of algae depends upon light and CO_2. Carbon dioxide is either available from bacterial oxidation of organic waste or by absorption, from atmosphere. It is apparent that,there are a number of interdependent factors onwhich the overall pond processes and their efficiency depends. Facultative ponds are designed with depths from2 to 5 feet. Facultative ponds have upper layers aerobic,lower anaerobic and incoming B.O.D. is stabilized in both the zones. Anaerobic stablization processes take longer time for stablizing organic matter.

Caldwell (10) Hermann and Gloyna (11) Van Heuvelen and Svore (12) have described facultative ponds. Fig-3, represents ecology of faculative pond.

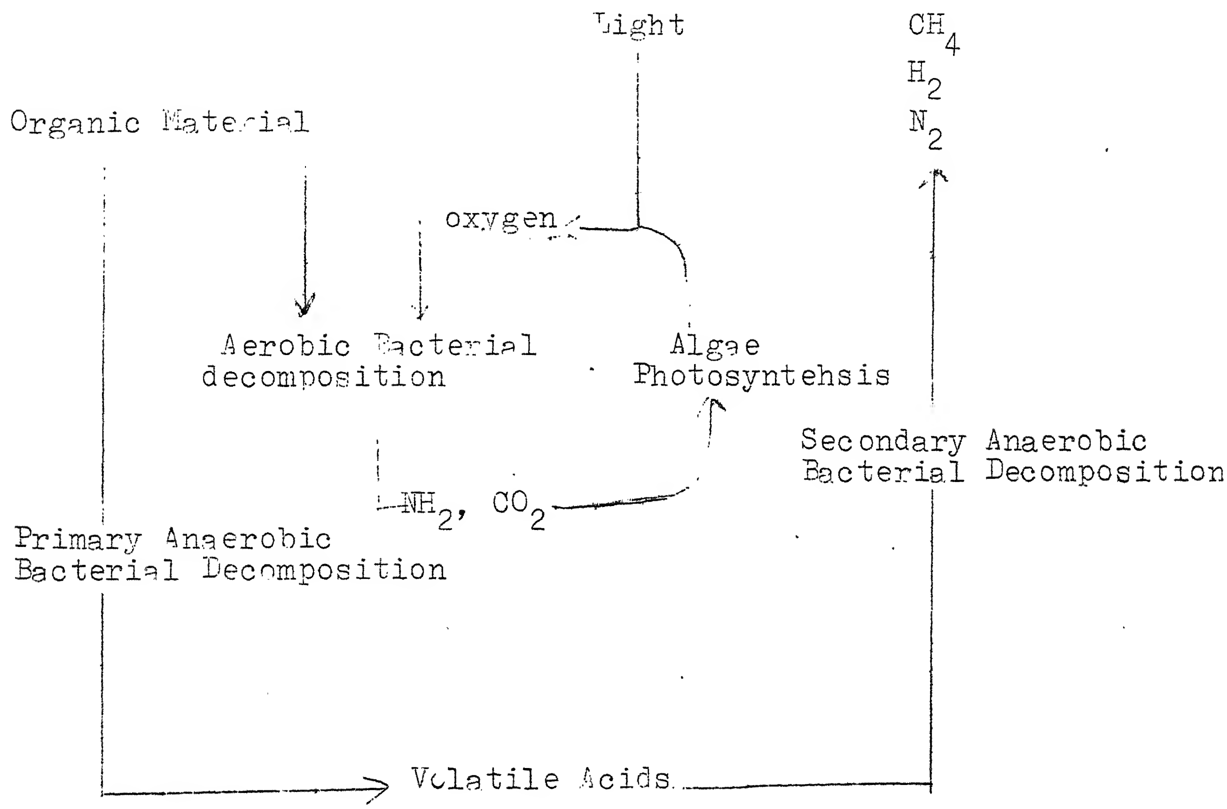


Fig.-3 SCHEMATIC DIAGRAM OF FACULTATIVE POND ECOLOGY

FACULTATIVE.

2.2 STABILIZATION BIO-REACTIONS IN THE POND:

As the wastewater enters a pond Sedimentations of the suspended organic matter starts. In the process even colloidal particles may be precipitated by the action of soluble salts which are concentrated by evaporation. This settled organic matter undergoes biological decomposition. This decomposition produces inert residue and soluble nutrients the nutrients produced deffuse into upper layers and algae use these nutrients for their metabolism. The colloidal and suspended organic matter is stabilized by simultaneious bacterial - algal interaction. Solar energy is utilized in photosynthesis and produces germicidal effect. Wind helps in mechanical distribution of dissolved oxygen and essential nutrients. Since photogsynthesis is dependent upon the penetration of light, layers beyond the reach of light become anaerobic. B.O.D. in such alyers is satisfied anaerobically.

2.2.1 TYPES OF DECOMPOSITION IN THE POND:

The decomposition of the sludge in the pond yeilds corbondioxide, ammonia, phosphates and some other compounds. If the pond is completely aerobic, the sludge is decomposed aerobically and most of the above componds are formed. In case there is no oxygen available in the bottom layers, partial or complete decomposition of the sludge may be caused anaerobically. Anaerobic decomposition takes place in two stages; first is Acid fermentation which will produce organic acids and the second stage is methane fermentation as a result of which methane gas is produced along with carbondioxide and hydrogen. Algae utilizes, CO_2, ammonia and phosphates evolved from bacterial decomposition, for their metabolism and release molecular oxygen. This oxygen is utilized by bacteria for degradation of organic matter.

2.2.2 DEPOSITION OF SLUDGE:

Deposition of the sludge to the pond bottom is a result of two processes, sedimentation and bioflocculation. Auto flocculation and fecal deposition by invertibrates occasionally help in sludge deposition in the ponds. Auto flocculation occurs when temperature and the pH levels in the ponds rise. Under these conditions certain componds present in hard wastewaters such as magnesum hydroxide, calcium sulphate and ammonium calcium sulphate, are

precipitated. These precipitates enmesh algal cells, organic matter and bacteria, form floc which readily settles down. Water coming out of the pond under this environment is soft

2.2.3 AEROBIC OXIDATION:

If the organic matter is completely stabilized aerobically, odor nuisance is prevented. It has been found that oxidation of sewage follows the reaction (13).

$$C_{11}H_{29}O_7N + 14\ O_2 + H^+ \longrightarrow 11CO_2 + 13H_2O + NH_4^+$$

In the above equation phosphorus, sulphur and trace elements are disregarded.

Significant oxidation of ammonia to nitrate does not occur in ponds because ammonia is either assimilated by algae or lost to the air.

2.2.4 AERATION FROM ATOMOSPHERE:

In continuously and heavily loaded ponds, a variable oxygen deficit develops, this may be due to certain prevailing conditions such as absence of green algae, continuous oxidation of organic matter and long detention periods. So the oxygen from the atmosphere has tendency to diffuse into the surface layers of the pond to restore saturation of dissolved oxygen in the pond. Imhoff and Fair (14) have established an approximate empirical

relation to give the quantity of oxygen which will enter a pond by reaeration.

$$R = 0.0271(a)\ (d)\ (D_o)$$

R - is reaeration in ponds per acre per day

d - is pond depth in ft

D_c- is the 24 hr average dissolved oxygen deficit

a - is assiged an arbitrary value of about 20.

A pond with oxygen deficit of 10 mg/l. will give rise to intolerable odors. Dissolved oxygen deficit upto 6 mg./l can be permitted.

2.2.5 PHOTOSYNTHESIS IN THE POND AND OXYGEN BALANCE:

The stablizationponds are nothing more than artificial housing provided to various algae population, so that these workers may join in the work of waste stablization. Algae by virtue of its chlorophyll, absorbs solar energy and fixes carbondioxide (released from lower layer of the pond) thus producing more algal cells.

Algal photosynethesis if the major potential source of oxygen for aerobic oxidiation in stablization ponds. Oswald(15) has given the following equations for the reaction

$$NH_4 + 7.6\ CO_2 + 17.7\ H_2O \longrightarrow C_7H_{8.1}O_{2.5}N_{1.0} + 7.6\ O_2 + 15.2H_2O + H^+ - 886\ Kcal$$

From this equation it can be calculated that about 3.68 Cal are fixed for each milligram of oxygen liberated and about 1.67 mg of oxygen are liberated for each millegram of algal synthesized.

The utilization of solar energy by algal cells can be represented by photosynthetis efficiency which is defind as fraction of the available solar energy converted to fixed energy in the form of algal cells(16).

The photosynthetic a light conversion efficiency is a function of light, time nutrient and temperature. To find out photosynthetic efficiency of a system, valvues for detention period, depth, and algal cell concentration are required. Oswald and Gotaas (17) have derived relations between photosynthetic efficiency, algal cell synthsis oxygen production. The chart going probable values of visible solar energy at different latitudes and in different months of the year have been published by Oswald and Gotaas(15).

They have established that for a pond which fulfils all its oxygen requirements through photosynthesis, the B O D loading can be equated as follows:

$$L_0 = 0.25\ F^c$$

WhereF is the photosynthetic efficiency at the given latitude and S is the solar radiation at that latitude. The algal concentration in the pond depends upon the ratio of oxygen production to algal cell material synthesized which according to the equation given before is 1.67. Thus by assuming that all the oxygen produced by photosynthesis is used for bacterial oxidation, the value of algal cell produced is given by the equation.

$$C_c = \frac{Lo}{1.67}$$

Lo is ultimate B O D to be satisfied in the pond, which equals BOD fed to the pond minus B O D going out of the pond. However practically it is not possible that all the oxygen produced by photosynthesis becomes available for oxidation. Some oxygen is lost during the period of super saturation in the pond having abundance of algal. The dissolved oxygen concentration increases to many times the saturation value under super satuation condition and a considerable part of the excess oxygen in the pond water is lost by deaeration. It is also desired to have some dissolved oxygen in the effluent from the pond. So a correction factor is introduced termed as oxygenation factor O_f, which is the value of total oxygen produced to total oxygen required.

$$C_c = \frac{L_o \, O_f}{1.67}$$

Myers(18) has shown that with oxygenation factors from 1.2 to 1.6, highest B O D removal is achieved, and at these values for the oxygenation factor, values for C_c would range from 0.72 to 0.92 that of L_o. The relation between algal concentration, light and depth is given by equation.

$$d' = \frac{L_n I_o - L_n I'_d \alpha}{C_c}$$

α is an absorption coefficient, L_n the light intensity at the pond surface, I'_d the intensity at depth, d', and C_c the culture concentration derived from equation given before. The intensity I_d, corresponds to the compensation point which is defind as the photosynthetic activity of the algal cell to meet its respiratory requirements. In most cultures, the value for the compensation intensity is about 20 ft.C.

α is a variable term and it depends upon pond depth as it increases with the increase in depth of the pond because the increasesed chlorophyll content of cells growing in light of low intensity prevailing in the deeper regions of the pond changes their light absorption characteristics.

2.3 POND ORGANISMS

The knowledge about various organisms flourishing in the pond is most important to ensure the effective perforamnce of the stabilization pond. The pond gives shelter to a number of varieties of organisms. The algae and bacteria are the most desired organisms.

2.3.1 ALGAE

The types of algae most active in stablization ponds are chlorophyta (green) and blue-green(cyanophyta). Typical of the algae in stablization ponds have been desribed by Arceiwala (19).

Blue green algae frequently flourish in ponds during summer months. Euglena has great adaptability to various pond conditions and are present during all seasons. Chlorella has maximum oxygen producing capacity and is most desired Algal cell contains on an average 50 to 60 percent proteins, 20 to 30 percent fat and 10 to 20 percent., Carbohydrates alongwith ~~xxxxx~~ amino acids and vitamins. So due to high protein content it can be used as a food. The empirical formulae for chlorella and Euglena are given below.

Chlorella	$C_7 H_{8.1} O_{2.5} N_1$
Euglena	$C_{7.62}H_{8.08}O_{2.53}N_1$

Along with the elements carbon, hydrogen, oxygen and nitrogen, algae also contain small amounts of phosphorus and sulphur.

2.32.

2.3.2 BACTERIA

The bacteria required for stabilization of organic waste come from sewage and soil washings in large number. The kind of bacteria will depend upon the prevailing conditions in the pond viz. aerobic, anaerobic or facultative. In anerobic conditions acid formers and gas formers are the most active bacteria.

2.3.3. PROTOZOA AND FUNGI

It has been found that protozoa which include all unicellular aminals exist in the ponds(19). Protozoa commonly occuring in ponds are.

Amoeba radiosa, A. proteus, Halosphaena sp., Euglypha, Stylonychia, Aspidisea, Paramecium, Vorticella and Carchesium.

Fungi grow in nearly neutral or slightly acidic condition. In ponds pH remains alkaline because of algal photosynthetic activity, so the growth of fungi is not encouraged.

OBJECTIVES OF THE PRESENT INVESTIGATION

The field investigation of stablization pond, receiving raw sewage from a small community of IIT, Kanpur,was conducted with the following objectives:

1. To determine the per capita BOD fed to the pond.
2. To achieve better understanding of the stablization mechanism occuring in facultative pond operating under natural conditions.
3. To correlate various operational parameters, responsible for the stablization of the raw sewage,in the facultative conditions.
4. The degree of treatment of the raw sewage,obtained.
5. To investigate whether there exists some stratification in the layers of pond water.
6. To evaluate design parameters for facultative pond under naturally existing conditions.

~~3.B EXPERIMENTAL PARAMETERS:~~

Any combination of chemical and biological system takes it own time to come to a **steady** state. Some preliminary observations carried out on **this** stabilization pond showed that the pond is working under steady state conditions. As this investigation has its mullifold objective, the defferent parameter's are classified according to the specific object:

To investigate stabilization mechanism paramters observed included.

a) Characteristics of the influent wastewater.

b) Oxygen production through photosynthesis.

c) Sediment.

d) Algae mass synthesized by absorption of solar energy

e) Production of gases.

Various parameters essential to investigate physical, chemical and biological phenomena undergoing in pond depths are:

PHYSICAL

a) Temperature of influent and effluent.

b) Volume of contents in pond.

c) Light intensity remaining at various depths.

CHEMICAL:

a) pH at various depth, this parameter is needed to peep into the pond depths to observe the types of decomposition taking place.

b) Dissolved oxygen would distinguish between aerobic and anaerobic zones.

c) Biochemical oxygen demand would detemine organic matter removals.

d) Total phosphates

e) Ammonia Nitrogen and Organic nitrogen: these deteminations help to study their variation in the effluent and influent and their recovery in the form of algal cell production.

f) Total solids, dissolved solids, settleable solids and suspended solids.

BIOLOGICAL:

The investigation was only restricted to observe the total count at various depths of the pond.

Following paramters were observed in the field and are correlated by developing an imperical relation.

a) Algal conc.

b) % light remaining

c) Dissolved oxygen.

d) Depth of the pond

Degee of Treatment obtained:

The influent and effluent composites were analysed for various characteristics to obtain degree of treatment of the raw sewage;

a) B O D 5 day, $20^{o}C$

b) C O D

c) Nitrogen, Ammonia and Organic

d) Total Phosphates

e) Total solids

f) Dissolved solids

To find out the existence of stratifications in the pond, the parameters observed include:

a) Dissolved oxygen at various depths.

b) B O D, 5 day $20^{o}C$ at various depths

c) Algal concentration at various depths

d) % Light intensity remaining at various depths

f) Total count at various depths.

g) pH at various depths.

To estimate aerobic and anaerobic B O D satisfacation proportions, the following parameters were studied:

a) Amount of gas produced from the anaerobic zone of the pond.

b) Oxygen produced photosynthetically in the aerobic layers.

C H A P T E R - 3

MATERIALS AND METHODS

3.1 Sewerage collection system of the IIT Campus

The Campus of Indian Institute of Technology, Kanpur, which occupies an area of 1040 acres comprise of residential buildings for staff, student hostels and academic and ancillary buildings. The Campus is served by a 24 hr. piped water supply from five tubewells and an elevated reservior which floats onthe distribution system. According to the rated capacities of the tubewells the total supply is 4×10^6 1/d (20).

All building on the campus have water flushed latrines and sufficient number oftap connections which drain to an underground sewerage system. Since the campus is located ona flat area, there are seven lift stations installed on main sewer lines and the intercepting sewer. The last lift pump is installed at the out fall, which pump wastewater to the stablization pond.

3.2 LOCATION, SHAPE AND SIZE OF STABLIZATION POND:

The sewage stablization pond which receives wastewater from the IIT/K campus is situated at about half a mile from the Institute bus stop towards north and behind theInstitute's air field. It is arectangular in shape, with a length of 400 ft, and breadth equal to 200 ft. It is $4\frac{1}{2}$ ft. deep (Fig.3.1). It has sloping sides which are laiden with open jointed bricks, however the bottom of the pond comprise of the natural earth to facilitate see page of the wastewater. It is provided with a pipe inlet,which is extended distance on the pond. According to design and plan the pond is to be provided with an outlet on the bank opposite to theinlet structure. But because of the delay in its construction, a provisional pipe outlet was employed during the first year of its operation near the middle of west bank of the stablization pond. The wastewater, from the campus is fed to the pond intermittently with the help of a pump,which is operated when the wastewater volume if accumulated suffciently.

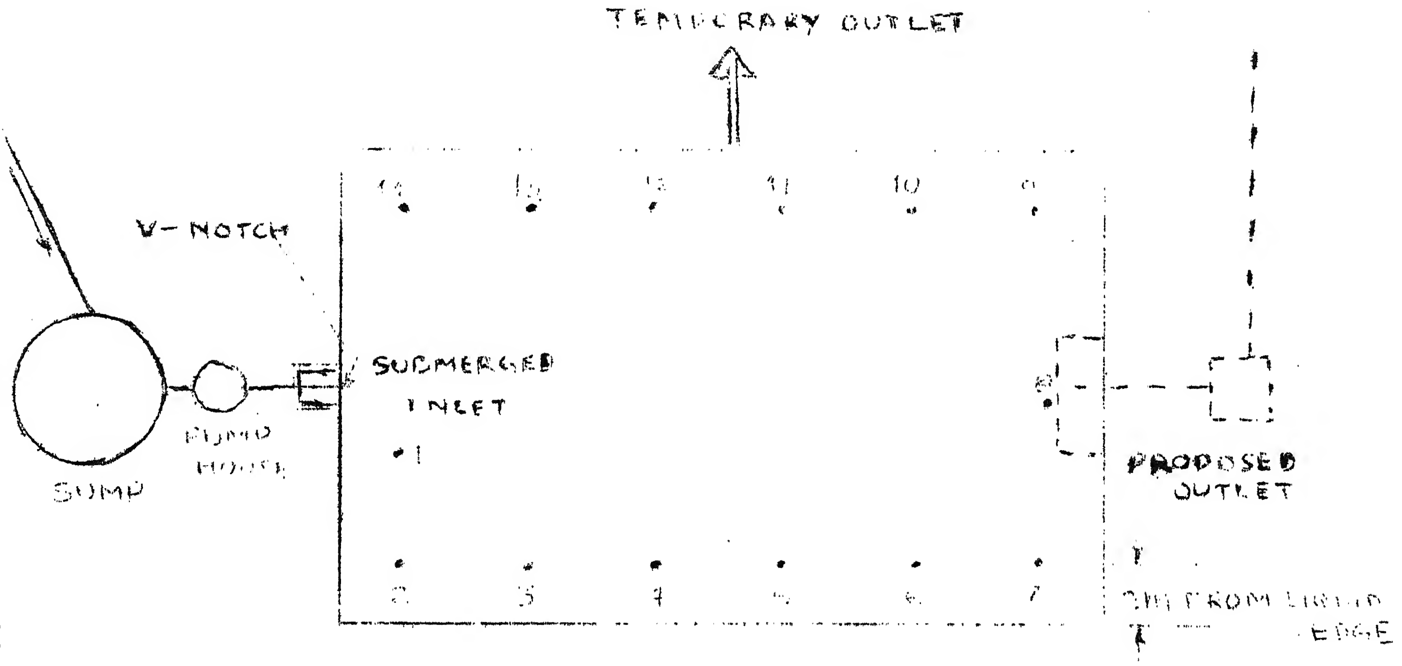


Fig. 3.1 SITE PLAN OF STABLLIZATION POND, I.I.T. KANPUR

3.3. EXPERIMENTAL PROCEDURES:

To achieve the proposed objectives, 14 sampling stations were selected all along the four banks, each station was about 10 feet from the bank inside the pond. Four stations were fixed on the long sides of the pond whereas three stations on the shorter sides as shown in figure (   ).

Most of the analyses were carried out in the sanitary Engineering Laboratory of the Institute, which is situated not very far from the pond. Ho ever certain observations and analysis were conducted on the site of the pond itself, whenever found necessary stored in the refrigerator to check any possible biological or chemical change in the samples during the time period of analysis. Samples after collection were transported to the laboratory as quickly as possible.

All dissolved oxygen and temperature determinations were made in the field immediately after the samples were collected. The concentration of investigations was in the summer months of 1969.

3.3.1. SEWAGE INFLOW MEASUREMENTS:

The inlet structure consists of a rectangular channel to the discharging end of which is fixed a right angular V-Notch the wastewater volume input to the pond was recorded

with the help of this V-notch. No measurements were made for the volume of treated sewage going out at the effluent end.

3.5.2 SAMPLING ARRANGEMENTS:

Since the inflow to the pond was inter millent, depending upon the pumping hours of the last lift station, sampling was also done during the time period the pump was operating. Samples were collected as soon as the flow in the influent channel started and every half an hour after that. There were immediately brough to the laboratory and stored at 3 to 4^{o}C for analyses.

The effluent samples were collected immediately below the outlet, the flow from the out let is continuous.

To collect D O samples at various depths of the pond a sampler as shown in Fig.(6) was used. There could be accomodated one standard B O D bottle inside the sampler.

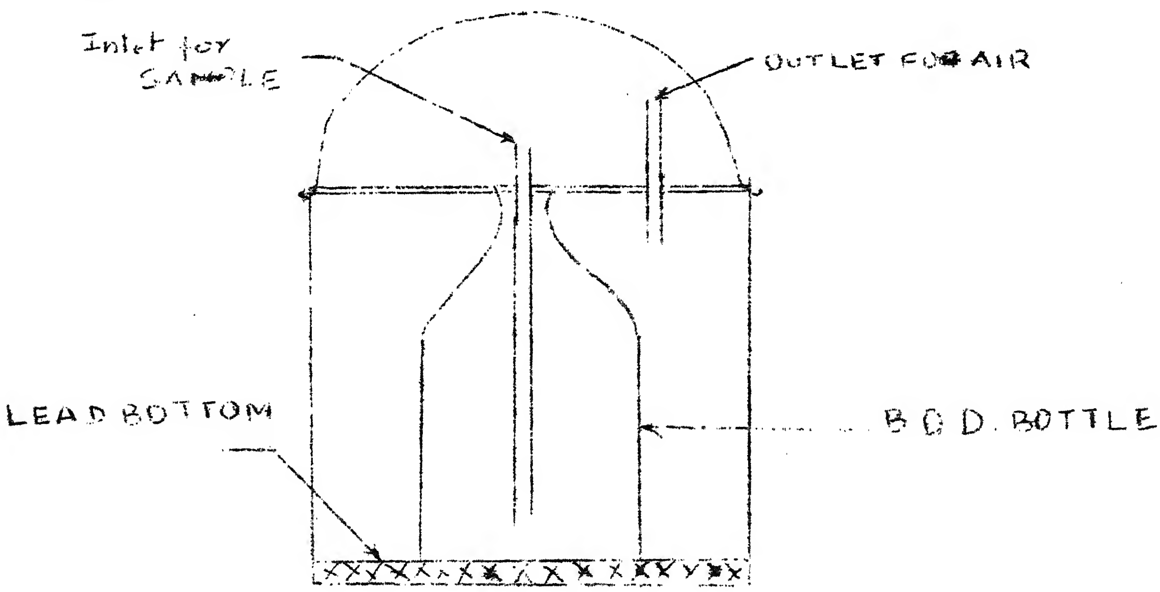


Fig-6 D O SAMPLER

As soon as the sampler dipped to the desired depth. wastewater started entering through the inlet pipe, where as at the same time the air entrapped escaped from the air outlet till the collecting bottle was filled upto the top.

3.3.3 GAS COLLECTION

To collect gases evolved in the anaerobic zone of the pond, appratus was designed the details which are shown in the figure(3.3). It consisted of a gas collecting chamber of 18 gauge glazed iron sheets. The dimensions of the chamber are marked in the figure. All joints of the chamber were made air tight. Three out let holes were kept on the top side of the chamber. These out lets were connected to gas collecting tubes with the help of transparent polythelene tubes. All joints were properly ensured for leack proofing. The gas collecting chamber was dipped to the bottom of the pond and the collecting tubes were placed in a stand, onthe bank of the pond. These tubes were connected to a gas collecting reservior . The pressure developed by the collected gas could push the liquid [illegible] down in the tubes to the attached reservoir. Thus volume

of the gas produced in a particular time period could be observed from the graduations marked on the tubes.

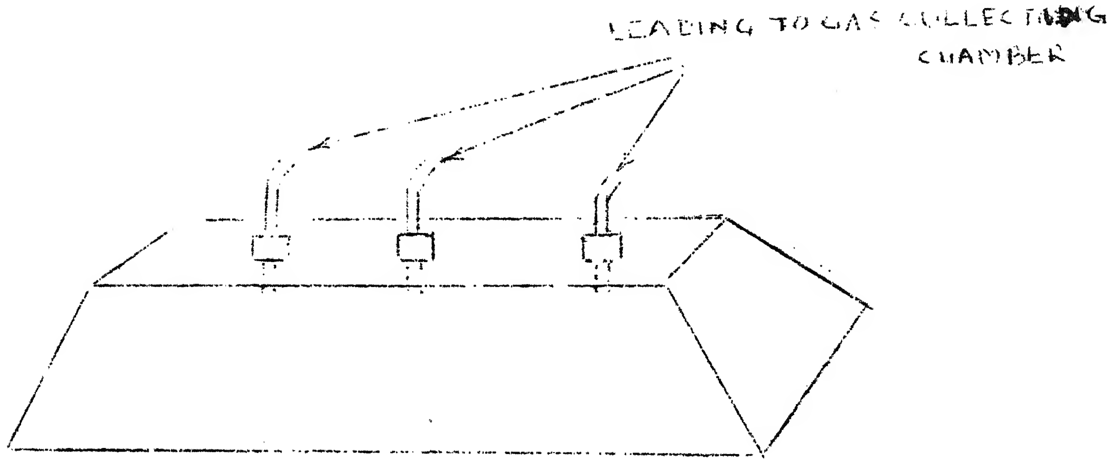


Fig3.4 GAS COLLECTING CHAMBER

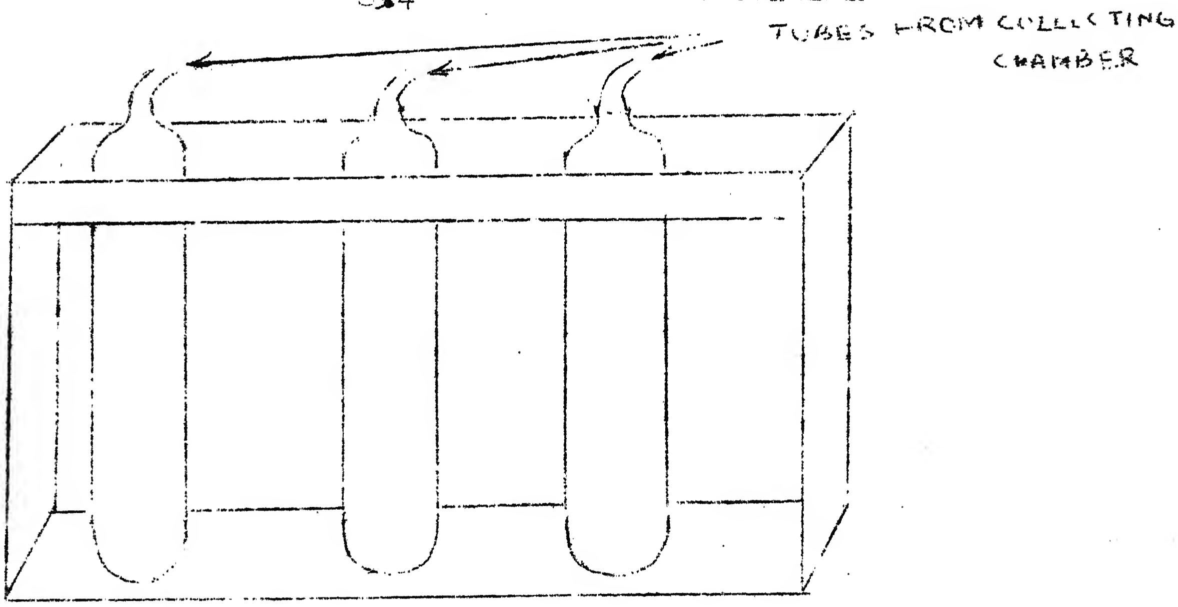


Fig3.5 COLLECTING TUBES

ANEAROBIC ZONE GAS COLLECTING ARRANGEMENT

3.3.4 MEASUREMENTS OF SOLAR ENERGY PENETRATIONS:

Light penetration into pond was measured at various depths in the pond, using a submerged photronic cell sensitive between 4200 and 7000 Angstroms. The cell was mounted on a diver and the leads attached to the cell were connected to a multimeter placed on the bank of the pond. The details of connections are shown in Fig. (9).

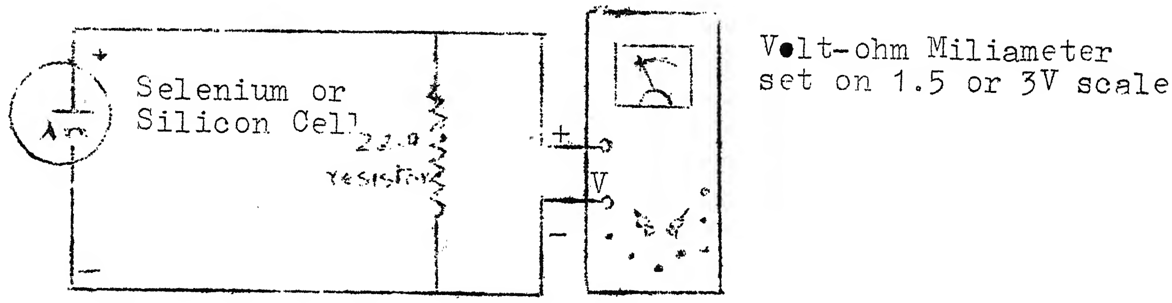


Fig.9 SOLAR ENERGY MEASUREMENT ARRANGEMENT

The photronic cell was of SIM type.

It is silicon cell in molded plastic case dimensions 1 1/8" x 1 1/8" 3/16".

3.3.5 DETERMINATION OF ALGAL CONCENTRATION:

As one of the main objectives of the present work was to estimate the algal protophlasm synthesized under prevailing conditions of light and temperature, the method of centrifuging the samples and seperating out algae for photoplasm determinations, was not adopted. In this method some

organic and biological matter other than algae would be centrifuged along with algal cells and errors are expected in the results. All the active types of algae in the pond have fixed amount of "chlorophyll A" as one of their constituents. The chlorophyll A content of the algae can be easily extracted with ethyl ether solvent. For standardization algae was harvested from a laboratory oxidation pond which was fed water and nutrients. 'ChlorophyllA' was extracted from different known wts. of dry algae taken from this pond and the absorbance of 'chlorophyll A' was found out at a wave length of 420 mμ for the different extractions, with spectrophotometer. Thus a curve was plotted relating wt. of algae in mg./l and absorbance of 'Chlorophyll A' content out of that algae as shown in figure(4.11). As no sewage was fed to the model pond, the possibility of errors in wt. determinations of algae due to additions of organic and other biological suspended matter, was reduced.

3.5.6 DETERMINATION OF OXYGEN PRODUCTION:

Oxygen production at the light intensities prevailing at various depths was measured. To do this, pond samples in glass-stoppered B O D bottles were suspended as selected depths in the pond. Half the bottles were blackended to exclude the effect of light. Oxygen change occuring during

the test period was used to determine mean hourly photo synthetic production and total respirating use of oxygen. All other determinations were made according to the methods established the book "Standard Methods for Examination of water and Wastewater (21)".

3.3.7 SETTLEABLE SOLIDS MEASUREMENTS

Settling material containing on stabilized organic matter, sludge and dead algal cells, was found out by sinking buckets of known weight and volume, at different sampling points. These buckets were taken out after a known period and the supernatant was clearly decanted off the remaining settling matter was weight after evaporating the moisture content in it.

3.3.8

COD, BOD, DO, PO_4, NO; etc. were determined according to the procedures described in standard methods for water and wastewater examination (21)

C_H_A_P_T_E_R-4

OBSERVATIONS AND DISCUSSION

4.0 Characterization of waste water from IIT-K Campus.

During the present study a house to house population census was carried out. The total population residing on the campus was 5441 persons. This includes 1728 students in the hostels. In addition to this population there were about 500 persons commuting from the city. This number is arrive at by considering the number of trips made by various buses of the institute in transporting the staff. Taking one fourth of above as effective population the total contributing population comes out to be5691. Observations for characterization work carried out on five consecutive days,which are shown in table.

TABLE : 4.0

CHARACTERISTICS OF WASTEWATER FROM IIT/CAMPUS

Determination	Day of Sampling 1	2	3	4	5
Temperature, ^{o}C	-	-	-	25-26	25-26
Total solids, mg./l	1048	1148	1104	1012	1008
Total suspended solids, mg./l	1438	620	600	305	345
Volatile suspended solids mg./l	155	265	-	222	60
Volatile dissolved solids mg./l	220	250	-	210	270
Ammonia nitrogen, mg./l	5.6	7.4	8.8	4.6	5.6
Organic nitrogen, mg./l	8.4	8.6	9.1	6.8	7.4
Total phosphates mg./l	4.5	5.2	5.0	6.0	5.4
Chlorides, mg./l	68.9	63.0	72.8	61.1	63.0
pH	7.6	7.8	8.3	7.9	8.2
COD, mg./l	240	284	278	314	278
BOD, 5 day, $20^{o}C$, mg./l	140	138	-	150	114
Rate constant, per day	0.1	0.1	-	0.098	0.24
BOD, ultimate, mg./l	205	203	-	221	125
Flow, 10^{6} l/d	3.16	2.67	2.34	2.83	2.99

4.1 TREATMENT OBTAINED

To access the efficiency of the pond processes in tr ating the raw sewage, composite of the influent and effluent were analyzed periodically for BOD 5 day 20°C, COD, Total solids, suspended soilds, dissolved solids, total phosphates, nitrogen organic and ammonia, pH, and algae in effluents. Tables 4.1 to 4.3 show the treatment of the raw sewage obtained. The influent and effluent samples were collected hourly over 24 hours period to make one composite for each. These composite of influent and effluent were characterized for various assessments: Table 4.4 shows the percentage reduction obtained in BO D, COD, Ammonia nitrogen, organic nitrogen and total phosphate concentrations.

Reduction of 5 day 20°C B O D in the season of summer ranged from 75 to 85 percent. The effluent samples contained large number of algae which join t e bacteria and other organisms in utilizing dissolved oxygen during the incubation of BOD samples in darkness Because filtering will emove living organic matter where oxygen demand is a valid part of BOD. Thus such BOD values are not strictly comparable to those of the influent sewage, however, they have been utilized in obtaining B O D reductions Table 4.4.

Looking at this obtained data it can be assessed that the pond is giving a satisfactory treatment of the raw sewage which is fed to it even without preliminary treatment.

The higher values of C O D for effluent is due to the presence of algal cells in the effluent samples as they were not removed before performing C O D tests.

A high percentage of the order of 62 to 71.1 of phosphate reduction was observed. It shows good amount of algae synthesis. Orthophsphate are assimilated during algae growth. The settlement of the phsphates to the bottom of the pond ~~of the~~ also caused decrease in phosphates in the effluent.

TABLE 4.1 TREATMENT OBTAINED

Date - 9-5-69 to 10.5.69

CHARACTERISTICS	INFLUENT	EFFLUENT
1. pH	7.2	8.6
2. D.O.	-	8.2
3. Temp	28.5 to 30.0°C	28.0 to 29.2°C
4. B.O.D	128 mg./l	28 mg./l
5. C.O.D.	240 mg./l	112 mg./l
6.a. Nitrogen-NH_3	4.0 mg./l	3.2 mg./l
b. Organic	-	-
7. Total Phosphates	10.0 mg./l	3.6 mg./l
8. Total Solids	1040 mg./l	850 mg./l
9. Total dissolved Solids	650 mg./l	610 mg./l
10. Algae Conc.	-	-

TABLE 4.2 TREATMENT OBTAINED

Date 30-5-69 - to - 31-5-69

CHARACTERISTICS		INFLUENT	EFFLUENT
1.	pH	8.1	8.7
2.	Temperature	30.5 to 31.8°C	30.0 to 31.5°C
3.	D.O.	-	9.0
4.	NH_3-N	9.24 mg./l	2.38
5.	Organic Nitrogen	9.60 mg./l	6.72
6.	Total PO_4	8.0 mg./l	2.3 mg./l
7.	B.O.D.	115 mg./l	28.mg./l
8.	C.O.D.	294 mg./l	158 mg./l
9.	Total Solids	110 mg./l	835 mg./l
10.	Total dissolved Solids	720 mg./l	520 mg./l

TABLE 4.3 - TREATMENT OBTAINED

Dates - 12-6-69 - 13-6-69

CHARACTERISTICS		INFLUENT	EFFLUENT
1.	pH	8.2	9.0
2.	Temperature	-	-
3.	D.O.	-	9.4
4.	B.O.D. mg./l	134.0	20.0
5.	C.O.D.	288.0	136.0 mg./l
6.	Total solids mg./l	1080	890
7.	Total dissolved Solids	688	610
8.	NH_3-Nitrogen	6.2	2.0
9.	Organic Nitrogen	6.8	3.7
10.	Total phosphates	6.4	2.4
11.	Algal Conc.	0	412 mg./l.

TABLE 4.4 TREATMENT OBTAINED

Date	Sample	B.O.D. 5 day, 20°C	C.O.D.	Ammonia Nitrogen	Organic Nitrogen	Total Phosphates
		PARAMETERS				
May 9-10 1969.	Influent	128	240	4.0	-	10.0
	Effluent	28	112	3.2	-	3.6
	% Reduction	78.1	53.4	20.0	-	64.0
May 30 - 31 69	Influent	115	-	9.24	8.6	8.0
	Effluent	28	-	2.38	6.7	2.3
	% Reduction	75.5	-	79.3	30.0	71.1
June 12 -13, 1969	Influent	134	288	6.2	6.8	6.4
	Effluent	20	136	2.0	3.7	2.4
	% Reduction	85	52.7	67.6	95.5	62.5

Analyses for ammonia and organic N determinations were prefomed shortly after sample collection to avoid any biochemical changes expected due to storage. The reducation in the ammonia nitrogen during the stabilization process is cheifly due to assimilation by algae where as organic nitogen is reduced by bacterial action. A large proportions of organic nitrogen is also converted to ammonia nitrogen in the pond.

The reducation in the total solids, suspended solids and volatile solids were also recorded. Table 4.1 to 4.3. The reduction in solids is attributed to two processes; sedimentation and utilization of organic past by bacteria and algae.

The high values of dissolved oxygen in the effluent exhibited effective photosynthesis in the pond.

The pH changes in the effluent were recorded and were found out to be 8.6 to 9 during various sets of observations. The pH changes in the effluent are related to algal activity. The high pH values are the result of good photosynthesis in the pond and where as lower values may result if anaerobic decomposition dominates in the pond. Hence pH values above 8.0 were produced by a photosynthetic rate that required more CO_2 than quantities given by respiration and decomposition pH level below 8.0 shows failure of photosynthetic to utilize completely amounts of CO_2 produced.

4.2 DIURINAL CHANGES IN pH AND DO.

Diurinal variations in pH and dissolved oxygen accompany changing rate of photosynthesis. The diurinal pattern of pH and DO in a pond can illustrate the changing bio-chemical environemnts in the pond. Photosynthesis decreases alkalmity by producing weekly soluble $caco_3$ that tends to precipitate, however decomposition and respiration increase alkalmity by brining back carbonate into solution as bicarbonate. Figures 4.1 and 4.2 give patters of diurinal variation of dissolved oxygen and pH respectively. The high pH values are indication of progressive photosynthesis and, therefore, a well accomplishing stabilization of organic matter by bacterial oxidation. In stabilisation ponds having abundant growth of algae, measurable oxygen largely represents photosynthetic production minus utilizationby decomposition and respiration and loss by diffusion to the atmosphere when super saturation is achieved. Diurinal records have shown zero values of D O at zero photosynthesis i.e. in night hours. This shows that measured quantities of dissolved oxygen are the result of photosynthetic production and the atmospheric reacration cannot cope with the requirements of aerobic decomposition process going on all the time in the pond. Thus the diurinal variations of dissolved oxygen exibit photosynthetic activity as well as bacterial oxidation undergoing in the pond. The peak values of dissolved oxygen were observed in the afternoon hours from 1.00 p.m. to 4.30 p.m. which can be concluded as hours of maximum

photosynthesis thus highest oxygen productionis in this period. Photosynthetic activity starts diminishing after 5.00 p.m. and because the sunset in the month of May and June is late around 7.p.m., a fairly high level of dissolved oxygen is maintained upto 9.p.m. However the dissolved oxygen level falls to zero after 10.30 p.m. and is not build up till the sunrise on the next day.

The pH variations over 24 hr. periods as illustrated by Fig.4.2 show maintenance of pH in the higher level, more than 8.0. The higher values of pH in the day time show the predominance of photosynthesis over respiration and decomposition. The lower values in the night hours are the result of stoppage of photosynthesis and CO_2 produced goes to solution as carbonic acid in the pond water. It has been observed that the highest values of pH were obtained around the hours of peak dissolved oxygen production. pH levels again start rising with the increasing photosynthetic activity in the morning hours of the next day after falling to minimum in the dark hours.

4.3. CHANGE IN SYSTEM PARAMETERS UNDER DIFFERENT CONDITIONS OF DEPTHS LOCATION AND HOUR OF THE DAY.

The interrelationship of oxygen productions, algae synthesis, pH and light intensity inside the pond can be established by executing studies of these parameters on various locations and at different depths of the pond. The stablizationprocess of the pond is dependent on the solar radiation and its penetration in the pond water. Furthermore the estimation of light intensities are important in three ways; firstly solar radiation is different at different latitudes, depends on the location of the pond, secondly seasonal changes in dialy solar radiation and finally penetration of incident light would tell about the volume of the pond water which would take part in oxygen production.

The illustrations in the Fig.4.3 to 4.5 show depthwise variation in D.O., % light, alge, pH, B O D 5 day 20^{o}C, and total bacterial concentration. All these observations were made on the same depth points at different stations in the pond. Four sampling points on the middle of each side of the pond, and above 50 ft. inside from the bank, were selected so that conditions prevailing all round the pond may be explored. Ninety percent of the incident light

Was absorbed in the upper 10 inch layer of the pond where as 99% of the incident light was absorbed in about 25 inch layer of the pond which shows a greater penetrations of the light. This shows that Euphotic Zone in this pond extends to a considerable depth where as 99% of the incident light was reported to be absorbed in 9" of the pond layer by field investigation at North Dakota Stablization ponds (22). This however can be reasoned out that in summer season at the latitude of Kanpur concentration of light radiation is much more than that at North Dakota and it also depends upon the concentrations of algae present in the pond water. So this can be stated that in this pond photosynthesis is taking pace upto about falf of the depth of the pond. The algae concentration was found out to be highest a few inches below surface. However the distribution of algae concentrations is uniform with depth. The temperature during observations ranged from 29 to 32°C.

The dissolved oxygen concentration in the pond decrease rapidly with depth, figure 4.4 to 4.6 at the depth of 20 inches, only 20 percent of the D O was remaining. However the zero D O values were not observed till the sludge blanket of the pond was reached. To estimate photosynthetic oxygen

production dark and light bottle experiment was performed on August 12, 1969. table 4.15. No significant variation was observed in light absorption data collected at various stations. In figure 4.12 average curve representing data collected is drawn. The penetration of light is plotted in fig. 4.12 according to Beers- Lambert Law.

$$\frac{I}{I_o} = e^{-\alpha c d} \qquad \text{------4.2}$$

Where I_o and I are intensities incident and after penetration through depth d respectively α is absorption coefficient, C is the concentration of algal cells. The value of αc comes out to be .09. Taking 300 mg./l of the concentration of algae in top 27" of the pond depth, α comes out to be 0.3×10^{-3} per/cm. Assuming that compensation point for the growth of algae, defined as the minimum intensity of light at which sufficient oxygen is produced through photosynthetic activity of algal cells (23) is reached at 2.57 cal/sq.cm. day (20 ft.C) depth of aerobic zone will be equal to 50 cm for incident solar radiation of 232 cal./sq.cm. day. Field observations have shown dissolved oxygen prevalance upto the depth 48" (110 cm.) from the top. It has been reported that aerobic environment occurs upto three times the depth given by equation 4.2 on basis of compensation pt. (23)

Table 4.15 shows the oxygenproduced in the pond, at different depths within a period of 5 hours. The negative values of D O in the dark bottles show the respiratory consumption of oxygen.

Photosynthesis can take place in a better way in open pond than in test bottles to which there is a likely hood of getting stuck some floating matter to hinder the penetrationof light rays. The values of D.O. ranged between 20 mg./l to 33 mg./l in the top 6 inch layer of the pond and this is more than three times the saturation level at the prevailing mean temperature of 25°C. on these days. However, a considerable amount ofoxygen is expected to be lost to the atmosphere because of prevailing high velocity winds, according to Oswald et.al (24) with an oxygenation factor of 2.0 more than half of the oxygen produced is lost to the atmosphere because of duration of period of supersaturation. The existenc of dissolved oxygen evenupto a depth of 40 inches very much tally with the observed deep light penetration upto 30 inches of depth. The vertical distribution pattern of D.O. were recorded on two different selected periods in a day, in the late morning hours around 11 A.M. and between 4 to 5 p.m. in the evening tables 4.8 to 4.10. The concentration of

dissolved oxygen on all the depths were not less in the evening hours than those in the morning hours, although solar radiation gets week in these hours. Two phenomenon, diffusion and vertical mixing may be accounted for this.

The hydrogen ion concentration patterns in the Fig. 4.3 to 4.6 show a slow decrease of pH with depths. The pH was never less than 8.0 at all depths of the pond even at the bottom. This confirms a well accomplished photosynthesis in the pond. The decrease in pH with depth is obiviously due to the decrease in photosynthesis with depth i.e. utilization of CO_2 goes on decreasing with depths.

The bio oxygen demand at different depths was found out at 20°C for 5 days, and the total bacterial count values were also obtained for the same samples of fig. 4.3 to 4.6. The low B O D values, maximum average value of 45 mg./l, indicates that a major portion of applied B O D is settled to the bottom in form of settleable solids. The legend of low B O D concentrations extends in the strata between 18 to 25 inches from the top. This is because of a high rate of bacterial oxidation in the region. The total count result does not seem to be accurate so they have not been taken for consideration.

4.31. EMPIRICAL RELATION AMONG OPERATIONAL PARAMETERS

Although Oswald (13) (17) (25) has related algal cell production and oxygen production at various light intensities. Yet there is nothing much done to discover the relationship among light intensity algal cell material, dissolved oxygen and depth of the pond under steady state conditions in the field.

In the present study by using a method based upon the principles of correlation analysis (26), simultanieous equations formed were solved by the use of Computer 1620 IBM.

X_1 = Algalcell concentration during a particular period in the pond in day time in mg./l

X_2 = % light remaining

X_3 = depth of the point of observation in the pond water in inches from the surface.

X_4 = Molecular dissolved oxygen, mg./l.

The relationship derived by solving the equation:

$$X_1 = a + b_1x_2 + b_2x_2^2 + b_3x_3^3 + b_4x_3 + b_5x_2^2 + b_6x_3^3 + b_7x_4 + b_8x_4^2 + b_9x_4^3.$$

With the use of computer the equation came out to be:

$$X_1 = 329.66 + 6.12x_2 + 0.5x_2^2 - 0.045x_2^3 + 7.68x_3 - 0.7x_3^2 + 0.0096x_3^3 + 0.036x_4 - 0.234x_4^2 + 0.014x_4^3$$

Now neglecting the terms of least effect and the equation obtained will be:

$$X_1 = 330 + 6.12x_2 + 7.68x_3 + 0.036x_4$$

so at depth where photosynthesis is at its peak the imperical relation comes out to be:

$$X_1 = 4.7 + 6x_2 + 0.04x_4$$

so the dissolved oxygen remaining in the euphotic zone can be linearly equated to % light reaching in the zone and algaal concentration prevailing

$$X_4 = \frac{x_1 - 6x_2 - 407}{0.04}$$

so this empirical derivation correlates light, algal concentration and dissolved oxygen existing at a particular depth under conditions of high temperature (30°C), bright whole day sunshine at latitude of Kanpur and in the month of June. There is a further scope of generalising the imperical relation if the no of sets of observations are taken all roundin the year and at different latitudes.

4.4 DO AND BOD CONTOURS AT STRATAS OF MAXIMUM AND MINIMUM PHOTOSYNTHETIC ACTIVITY

Nine inches below the surface of pond was thought over as the region of maximum photo-activity and bottom of the liquid layer (from where sludge blanket starts) the area of least activity. Furthermore it was considered that the reaction of photosynthesis, because of various factors like turbidity, wave action et, might not be of equal strength at various places in the pond. DO concentration in the different pond layers are also dependent upon the microbial consumption of oxygen. To obtain the dissolved oxygen pattern at depths of 9" below surface and at bottom, D O observations were made at 14 stations selected all round the pond and well within from the sides, and to acess the effect of time (solar radiation is different at different times) the observations were taken in the early morning hours 6 - 7 A.M. and late evening hours 4 to 5 P.M. This has for the enabled to access the extent of photosynthesis in these hours of minimum prevailing light. Contouring of the regions 9" below and at bottom gives wider vision of the prevailing dissolved oxygen and bio-oxygen demand in the pond. The contours drawn with the available data help to estimate D O and B O D at any point in the pond, 9" below and at bottom of the pond approximately. This also

help to locate the regions of photosynthetic activity. At 5 P.M. on 14th May, 1969 the D O concentrations are only localized in the   corner left to inlet structure, at the bottom of the pond where as zero DO values were observed on rest of the pond bottom. Between 6 A.M. to 7 A.M. on May 15, 1969 D O concentrations are localized in left corner beyond the outlet pipe, at 9" below and at bottom, but between 4 to 5 p.m. on May 31, 69 DO is well spread all round in the pond at 9" below and bottom of the pond, this shows that at this hour of the day consumption of the evolved xoygen has not exceeded the production and the pond is performing aerobically even upto the bottom. Figures 4.7 to 4.9 illustrates DO contours.
B O D contours at 9" below pond surface on June 11, 1969 are drawn in Figure 4.10.

4.5. MASS BALANCE OF ORGANIC MATTER:

4.5.1 SURFACE LOADING:

Average results of five composite samples each collected over a period of 24 hours for influent and effluent are shown in below. These values result in a BOD loading of 640 Kg/hectare day (575 lb./acre day) and a theoretical detention time of 3 days.

Characteristics of influent and effluent

Parameter	Influent	Effluent
Flow, 1/d	2.8×10^6	2.7×10^6
BOD, 5 day 20^oC, mg./1	135	25
COD, mg./1	240	135

4.5.2 ALGAL SYNTHESIS AND OXYGENATION:

The extent of algal synthesis and concomitant production of oxygen can be estimated by considering the available solar radiation, efficiency of utili ation of this energy by algae for synthesis, calorific value of algal cells and ratio of oxygen produced to cellular material synthesized(23).

Taking these values respectively as 232 cal/sq.cm. day, 6 percent, 6000 cal/g and 1.67 the algal synthesis and oxygen productionequal 137 kg./day and 208 kg./day respectively.

4.5.3 ALGAL FLOCCULATION AND SEDIMENTATION:

From the characteristics of effluent from the pond given in table above it is seen that the ratio of BOD to COD is very much lower as compared to that of the influent. This is mainly due to the presence of algae in the effluent which exerts an insignificant amount of BOD but is oxidized chemically. Taking BOD to COD ratio same as that for influent for other organic matter, COD due to algae only comes out to be 90 mg./1. This correspondes to a cellular concentration of 54 mg./1. Therefore the total amount of algae going out in the effluent is 140 kg/day. Comparing this with 137 kg/day, the algal synthesis, it is seen that there is no sedimentation of algae. Furthermore it shows that the efficiency of utilization of radiation is equal to 6 percent as assumed earlier.

The reactions of organic matter in the aerobic and anaerobic zones of a facultative pond are shown schemetically below. Liquifaction of settled organic matter in the anaerobic zone and its release to aerobic zone has been omitted as liquified products are quickly converted to gases which escape

as bubbles under efficient conditions of operation. The reactions and balance shown in this figure can also be represented, at steady state, by the following equations:

$$L_1 = L_3 + L_4 + L_5 \qquad \text{....(a)}$$

$$L_7 = L_2 + L_5 + L_6 \qquad \text{....(b)}$$

Where L_1 to L_7 represent, respectively, BOD of non-settleable organic matter in influent, settleable organic matter in influent, organic matter ineffluent, organic matter oxidized in aerobic zone, bacterial mass synthesized in aerobic zone, algal mass settling to the bottom and organic matter decomposed anaerobically

From the foregoing observations and assuming one third of the influent BOD as settleable and 0.5 as the ratio of synthesis to substrate utilized in aerobic systems, equations a and b yield.

$$\begin{aligned} L_4 &= L_1 - L_3 - L_5 \\ &= \frac{1}{2} \left(\frac{2}{3} \times 135 \times 2.8 - 25 \times 2.7 \right) \times \frac{1}{0.683} \\ &= 135 \text{ kg./day} \end{aligned}$$

and

$$\begin{aligned} L_7 &= L_2 + L_5 + L_6 \\ &= \frac{1}{3} \times 135 \times 2.8 + \frac{1}{2} \left(\frac{2}{3} \times 135 \times 2.8 - 25 \times 2.7 \right) + 0 \\ &= 320 \text{ kg/day} \end{aligned}$$

assuming BOD rate constant as 0.1 per day at 20°C.

It is apparent that a major portion of BOD removed is due to anaerobic reactions. Therefore an effort should be

in designs to provide a suitable. envionment to support anaerobic activity. In the present case, it is seen, that dissolved oxygen penetrated almost to the pond bottom when photosynthetic activity was maximum. It is known that organisms respnsible for gassification, methane producing bacteria in particular, are extremely sensitive to oxygen. Therefore, it seems advisable to provide greater liquid depths. Minimum liquid depths between 1.5 and 2 m seem to be more appropriate as compared to 1.2 to 1.37 m usually recommended.

From the value of oxygen produced due to photosynthesis (208 kg/day) and that consumed for oxidation (L_4 = 135 kg/day) the oxygenation factor for the pond comes out to be 1.61. This value, it is felt, would be lower during colder months because of a decrease in photosynthetic activity and an increase in solubility of oxygen.

Oxygen produced during the month of December through photosynthetic activitywould be 112 Kg/day assuming available radiation to be 140 cal/sq.cm.day. It is seen that this production ofoxygen is still sufficient as evidenced by satisfactory operation of the pond. Comparing this value with L_4during December, calculated by taking effluent BOD as 40 mg/1, the oxygenation factor comes out to be 1.20 which is an acceptable value for satisfactory operation(23). It is concluded, therefore, that for facultative stablization ponds the surface area should be calculated on the basis of oxygen

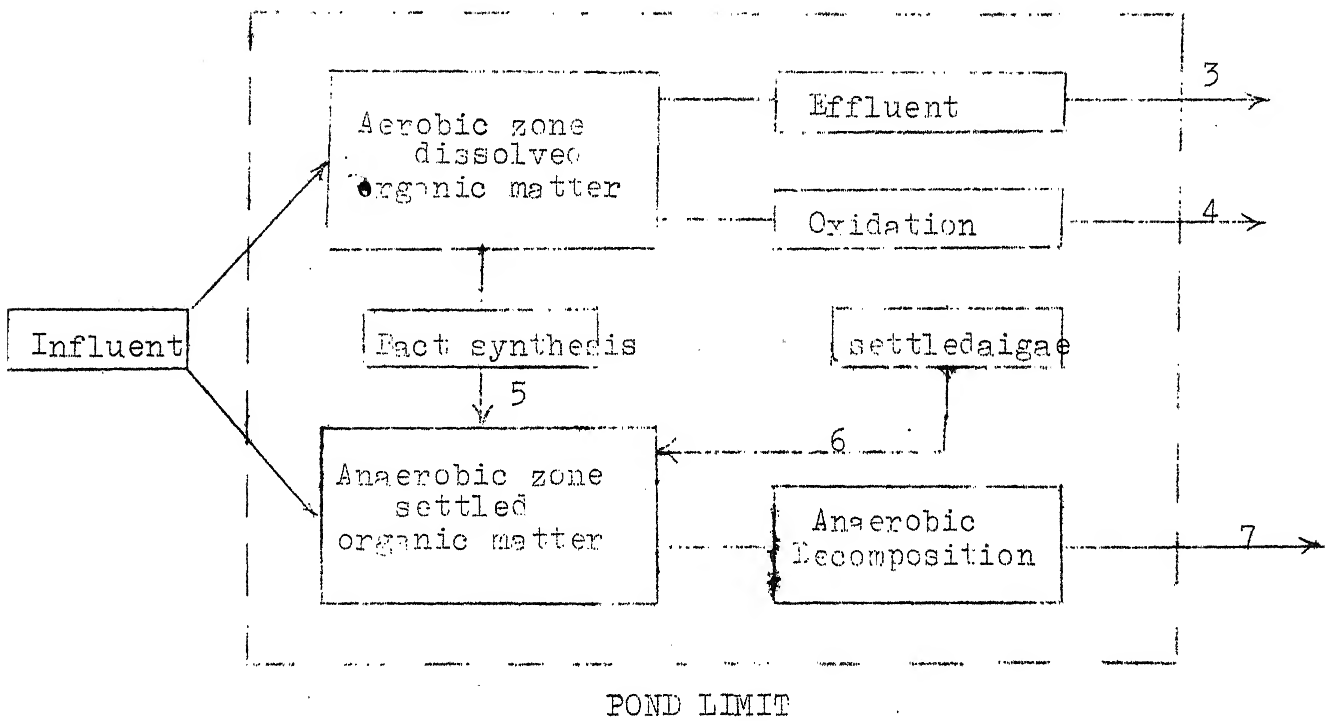
requirement for stablization of half of the non-settleable BOD fraction in the influent.

The detention time likewise would be calculated by considering only half of the non-settleable BOD load. For the present case using a BOD rate constant as 0.158 per day at $30^{\circ}C$ and effluent BOD value of 25 mg./1 the detention time comes out to be 1.62 days which is less than the actual value of 3 days.

The observation that the effluent was devoid of dissolved oxygen during night is probably due toshort circuiting. A better utilization of the available oxygen would have occured if the outlet was located at the far end of the pond.

4.5.4 ANAEROBIC STABLIZATION OF BOD.

The field observations have yeilded anaverage value of anaerobic satisfaction of BOD of the order of 74 lbs./acre/day. This is not comparable to the value of L_7,which equals 382 lbs./acre/day. This difference in ~~r~~ results is due to a possible leakage of gas during collection. The observations made on settleable solid collections have confirmed that the accumulation of solids is not same throughout the length of the pond. The gas collection could only be made at the far end of the pond where the solid accumulation was observed to be minimum. This may be another reason for the wide difference in the values.



. REACTIONS OF ORGANIC MATTER IN A FACULTATIVE STABILIZATION POND.

4.6 PHYSICAL APPEARANCE OF THE POND DURING STUDY

The pond was under observation from the month of May to the month of August,69. Pond never created serious oder nuisance during these months, which shows a satisfactory performance of the pond under aerobic conditions, although the sludge digestion, in one foot sludge zone, takes place anaerobically with the production cf slduge gases.

Floating algae mats were seen occasionally during the month of July and August. They were developed from detached benthic algae (phormedium) which floated to the surface. The mats are driven from corner to corner with changes in wind direction. They, however, did not last long this shows that the wind action was strong enough to break them.

The bluish green appreance of the pond water was due to the rich harvest of algae in the pond. The deep bluish green colour of effluent shows the presence of a good amount of algaal cells going out.

The strong summer winds in the months of May, June and July, kept the pond water well stirred. Detention time in the pond could not be found out inspite number of attempts were made by using salt solutions as well as dyes.

TABLE: 4.5

VARIATION IN INFLUENT & EFFLUENT CHARACTERTISTICS

Date : 9-5-69 - 10-5-69

TIME	INFLUENT			EFFLUENT		
	pH	D.O	Temp.	pH	D.O	Temp.
11.0 A.M.	–	–	–	8.65	9.2	29.0°C
1.0 P.M.	7.3	–	30.0°C	8.80	9.4	29.0°C
3.0 P.M.	–	–	–	9.10	10.2	29.2°C
5.0 P.M.	7.4	–	30.0°C	8.90	10.6	29.1°C
7.0 P.M.	7.6	–	30.0°C	9.00	10.8	29.0°C
9.0 P.M.	7.4	–	29.5°C	8.50	0	29.0°C
11.0 P.M.	–	–	–	8.50	0	29.0°C
1.0 A.M.	–	–	–	8.60	0	28.0°C
3.0 A.M.	–	–	–	8.60	0	28.0°C
5.0 A.M.	7.2	–	28.5°C	8.60	0	28.0°C
7.0 A.M.	7.2	–	28.5°C	8.60	0	28.0°C
9.0 A.M.	7.3	–	–	8.90	9.3	28.5°C

TABLE : 4.6

VARIATION IN INFLUENT & EFFLUENT CHARACTERISTICS

Date: 31-5-69

Time	INFLUENT			EFFLUENT		
	pH	D.O. mg./l	Temp.	pH	D.O mg./l	Temp.
9.30 A.M.	8.0	-	30.5°C	8.8	1.0	30.0°C
11.30 A.M.	7.5	-	31.0°C	8.9	4.2	30.3°C
2.0 P.M.	7.2	-	31.5°C	9.1	4.8	31.2°C
5.0 P.M.	7.4	-	31.5°C	9.3	4.7	31.5°C
7.0 P.M.	-	-	-	9.1	8.6	30.1°C
9.0 P.M.	-	-	-	8.9	4.8	30.0°C
11.P.M.	7.6	-	31.0	8.8	0	30.0
1.A.M.	-	-	-	8.5	0	30.0
5.0 A.M.	7.5	-	30.5	8.6	0	30.0
6.0 A.M.	-	-	-	8.4	0	30.0

TABLE : 4.7

VARIATION IN CHARACTERISTICS OF INFLUENT & EFFLUENT

Date: 11-6-69 - 12-6-69.

Time	Influent			Effluent		
	pH	DO	Temp.	pH	D.O	Temp.
8.30 A.M.	7.6	–	31.0°C	8.9	4.8	30.5°C
10.30 A.M.	–	–	–	8.8	6.0	31.0°C
12.30 P.M.	–	–	–	8.9	10.0	31.2°C
2.30 P.M.	7.8	–	32°C	8.9	12.0	31.5°C
4.30 P.M.	8.0	–	31.8°C	9.2	12.0	31.5°C
6.30 P.M.	–	–	–	9.0	5.0	31.0°C
8.30 P.M.	–	–	–	8.8	3.2	30.8°C
11.00 P.M.	–	–	–	8.5	0	30.0°C
1.0 A.M.	7.6	–	30.8	8.6	0	29.0°C
4.0 A.M.	–	–	–	8.6	0	28.8°C
6.0 A.M.	–	–	–	8.7	2.0	29.0°C
8.30 A.M.	7.8	–	–	8.8	5.8	30.0°C

TABLE : 4.8

DISTRIBUTION OF VARIOUS PARAMETERS

Date - 21-5-69 - Time 3 to 5 P.M.

DEPTH FROM SURFACE

	9"	18"	30"	48"
Station-I				
D.O mg./l	30.0	13.2	2.4	2.0
pH	-	9.2	8.9	8.8
B.O.D.	29	24	28	30
Station-II				
D.O.	24.6	17.0	4.4	0
pH	9.4	9.4	9.0	8.8
B.O.D.	31	28	28	34
Station-III				
D.O.	18.0	15.0	3.6	0
pH	-	9.2	9.0	-
B.O.D.	-	-	-	-
Station-IV				
D.O.	16.4	8.6	4.2	0
pH	9.2	9.0	8.8	8.8
B.O.D.	41	26	-	-

TABLE: 4.9

VERTICAL DISTRIBUTION OR VARIOUS PARAMETERS

Date 7-6- 69 Time 11.A.M.

DEPTH FROM SURFACE

Station-I	9"	18"	30"	48"
D.O.	17.2	12.6	6.0	0
pH	9.6	9.4	9.1	8.9
Station-II				
D.O.	20.C	13.4	6.6	0
pH	9.4	9.0	9.0	8.9
Station-III				
D.O.	19.2	14.8	5.0	0
pH	9.4	9.2	9.0	8.8
Station-IV				
D.O.	16.2	14.2	4.0	0
pH	9.4	9.1	9.0	8.5

TABLE : 4.10

VERTICAL DISTRIBUTION OF VARIOUS PARAMETERS

Date : 25.6.69 Time 3-00 P.M.

DEPTH FROM SURFACE	9"	18"	30"	48"
Station-I				
D.O. mg./l	2.4	2.0	16.6	11.6
pH	9.8	9.6	9.4	9.2
% light remaining	17	2	.02	0
Algae con. mg./l.	440	330	200	130
B.O.D. 5 day mg./l.	56.0	22.0	32.0	28.0
Total concent.	$65x10^4$	$32x10^4$	$38x11^4$	$36x10^4$
Station-II				
D.O	17.0	13.4	3.6	2.0
pH	9.8	9.3	9.1	9.00
% light remaining	11	3	.04	0.
Algal conc.mg./l	380	275	150	112
B.O.D. 5 day mg./l	44.0	26.0	25.0	30.0
Total Concent.	-	-	-	-
Station-III				
D.O.	14.0	8.4	6.0	0
pH	9.5	9.2	9.0	8.8
% light rem.	12	3	0.04	0
Algal conc. mg./l	410	325	200	135
B.O.D. mg./l	30.0	26.0	28.0	36.0
Total cont.	$27x10^4$	$27x10^4$	$30x.10^4$	$32x10^4$

Station-IV

D. O.	17.0	6.6	3.4	0
pH	9.5	9.2	9.0	8.8
% light rem.	11.0	3.0	.04	0
Algal conc. mg./l.	460.0	330	180	160
B.O.D. 5 day 20°C mg./l	36	28	20	32
Total cont. per litre.	41×10^4	33×10^4	28×10^4	42×10^4

TABLE : 4.11

D.O. CONCENTRATION 9" BELOW SURFACE & AT BOTTOM

Date: 14-5-69 Time - 5.P.M.

Station No.	DEPATH 9" below	Bottom
1.	30.0 mg./l	1.8 mg./l
2.	-	-
3.	24.8 mg./l	10.4 mg./l
4.	20.2 "	0
5.	19.2 "	0C
6.	18.0 "	0
7.	20.8 "	0
8.	24.8 "	0
9.	20.4 "	0.4
10.	27.4	0
11.	27.8	0
12.	26.8	0
13.	32.6	0
14.	-	-

TABILE: 4.12

D.O. CONCENTRATION 9" BELOW SURFACE & AT BOTTOM OF THE POND

Date : 15-5-69 Time 6.A.M. to 7.A.M.

Station No.	DEPTH 9" below surface	bottom
1.	0	0
2.	–	–
3.	0	0
4.	0.6	0
5.	0.6	0
6.	0.6	0
7.	1.4	0.8
8.	3.8	0.2
9.	1.4	0
10.	2.2	1.0
11.	0	0
12.	1.2	–
13.	–	–
14.	–	–

TABILE : 4.13

D.O. CONCENTRATIONS 9" BELOW SURFACE AND AT BOTTOM

Date: 31-5-69 Time 4.0 P.M. to 5.00 P.M.

Station No.	D.O.mg/1 9" below surface	bottom
1.	20.2	4.5
2.	21.0	0
3.	16.2	0
4.	15.0	0
5.	22.5	18
6.	17.1	0
7.	13.8	0
8.	16.5	1.8
9.	24.6	3.0
10.	24.9	0
11.	20.4	0
12.	13.8	2.0
13.	20.4	0
14.	21.0	0

TABLE: 4.14

D.O. CONCENTRATION 9" BELOW SURFACE AND AT BOTTOM OF THE POND

Date 1-6-69 Time 4.A.M. to 5 A.M.

Station No.	9" below surface	bottom
1 to 4	zero	zero

TABLE 4.15

DISSOLVED OXYGEN PRODUCTION DURING FIVE HOURS
AT DIFFERENT DEPTHS: [illegible] Aug.12,1969

Time: 8 a.m. to 12.[illegible]

% Surface light	Depth in inches	DO change mg./l light bottles	bottle	Oxygen production per hr. mg./l.
17	9	+ 14.0	-3.2	3.4
3.5	18	0.0	-3.1	0.6
0.4	30	-1.5	-3.0	0.3

TABLE 4:16

LIGHT INTENSITY REMAINING AT VARIOUS DEPTHS

Date : 1-6-1969 Time 11 A.M.

Station No.	% Light intensity remaining Depth Top							
	4"	6"	9"	12"	18"	24"	30"	45"
1	50	27.7	16.6	5.0	2.5	0.5	.25	0
2.	33.0	22.0	11.0	7.0	3.0	1.3	.4	0
3.	33.0	16.0	11.0	4.4	1.8	1.1	030	0
4.	38.8	22.0	16.6	11.0	3.8	1.6	.50	0

TABLE 4.17

GAS PRODUCTION FROM THE SLUDGE ZONE

Date	Volume of Gas cft./acre/day	BOD satisfied anaerobically.
5.8.69	890	89 lbs./acre/day.
6.8.69	590	59 "
7.8.69	670	67 "
8.8.69	810	81 "

.....

TABILE : 4.18

B.O.D. CONTOURS 9" BELOW SURFACE

Date : 11-6-69

Station No.	B.O.D. 5 day 20°C 9" below surface
1.	26.0
2.	58.0
3.	56.0
4.	40.0
5.	–
6.	26.0
7.	28.0
8.	26.0
9.	24.0
10.	10.0
11.	28.0
12.	42.0
13.	48.0
14.	34.0

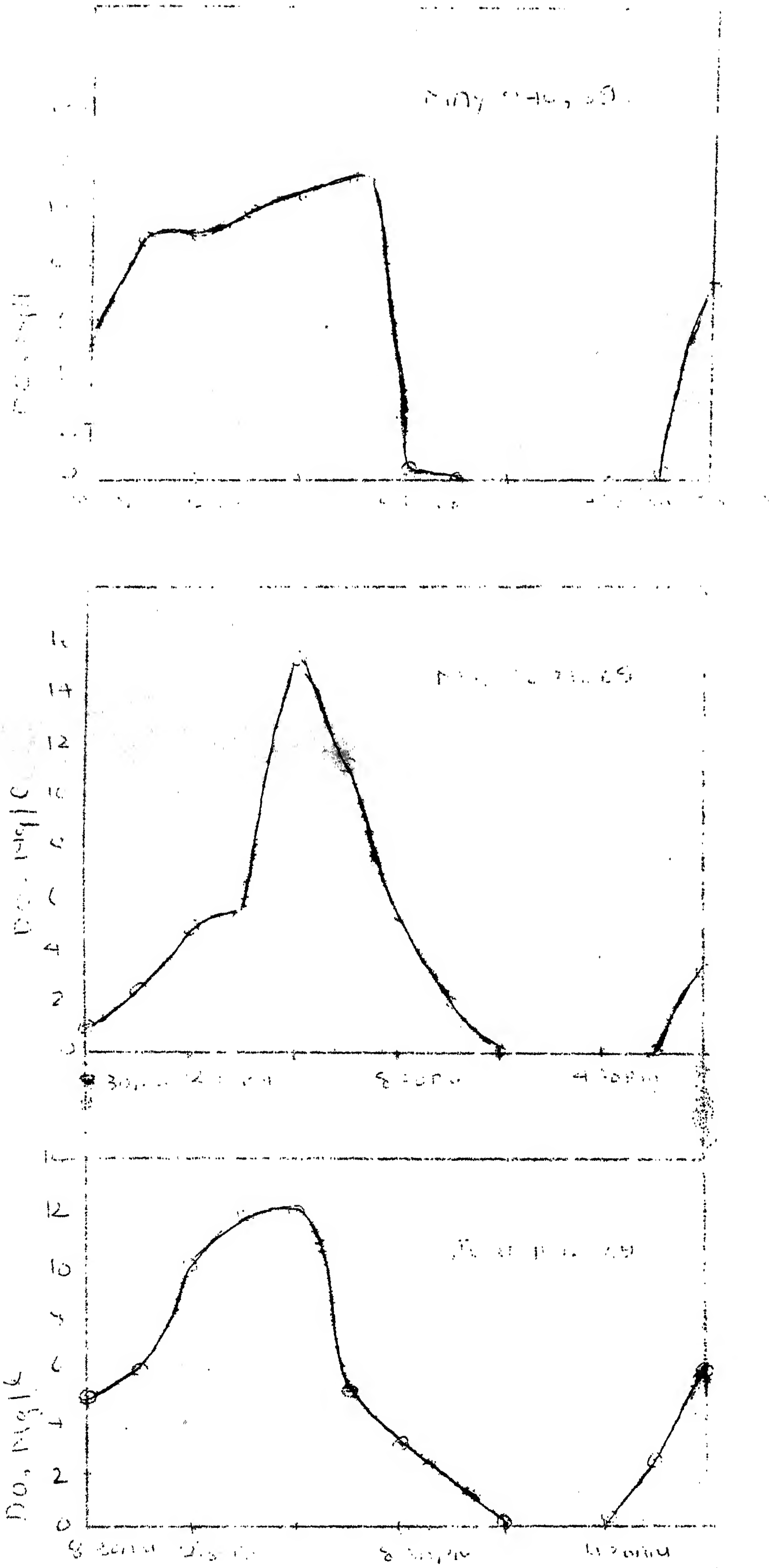


Fig.4.1 DIURINAL VERIATION OF D.O.

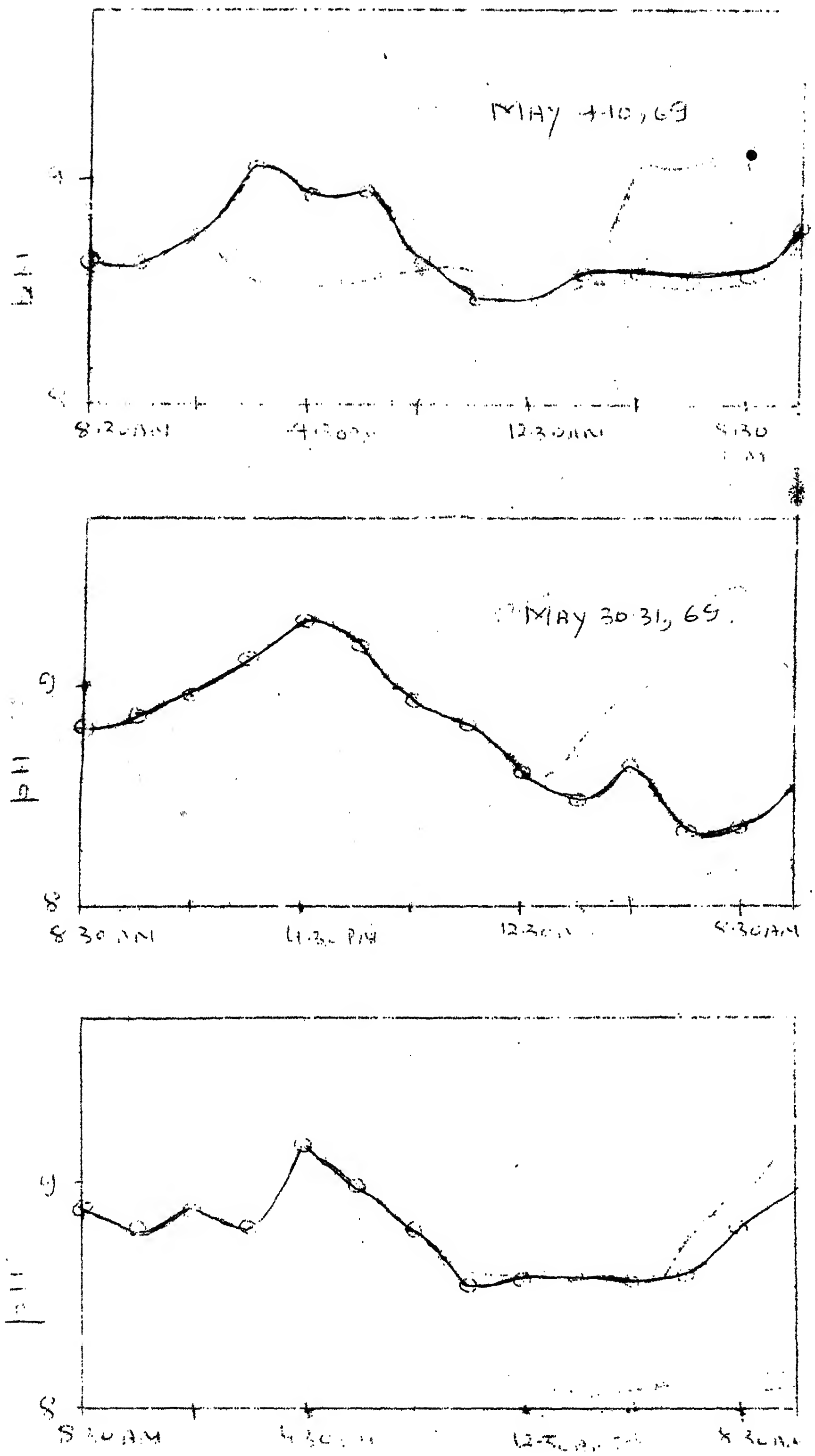


Fig: 4.2 DIURINAL VARIATION IN pH.

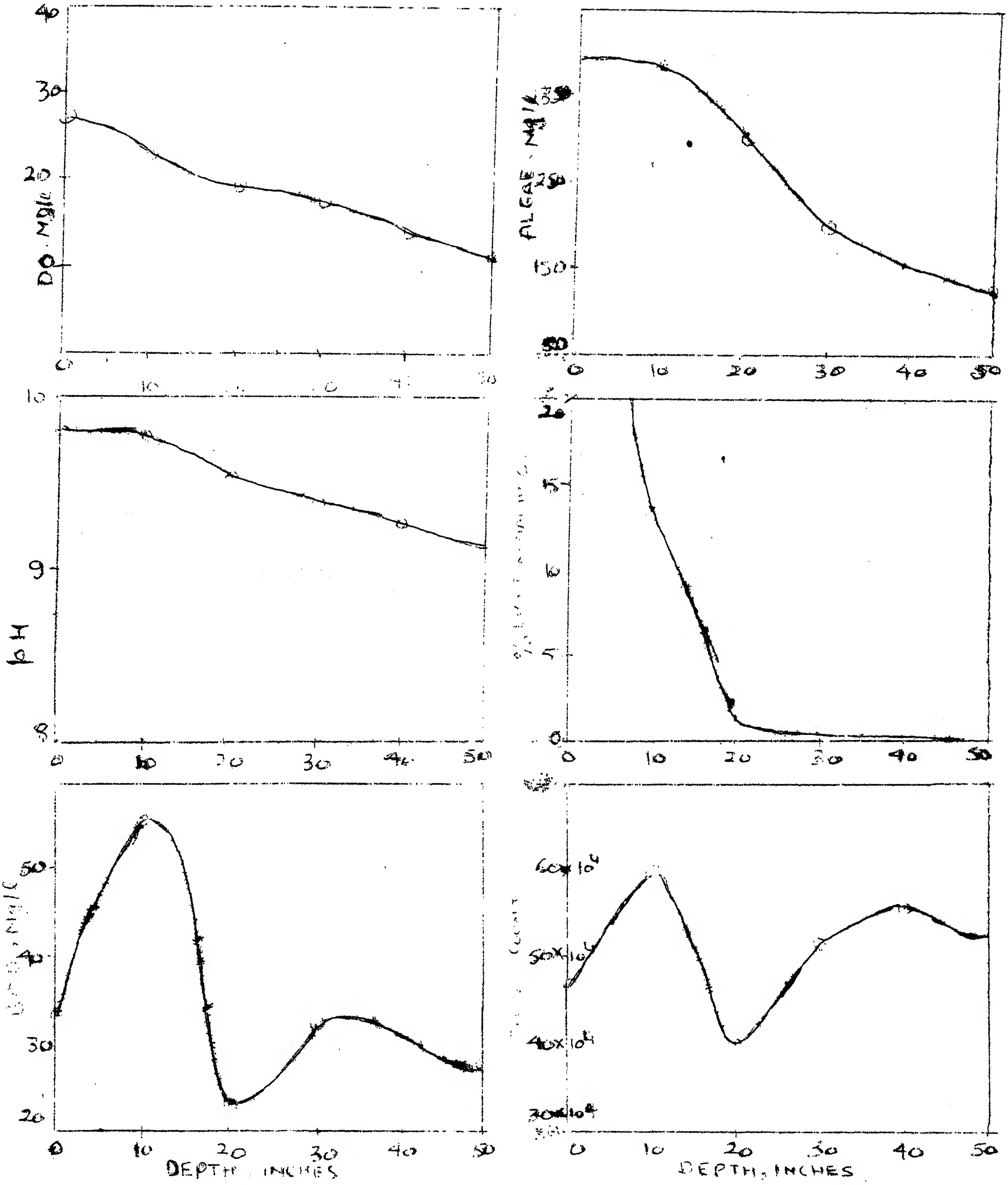
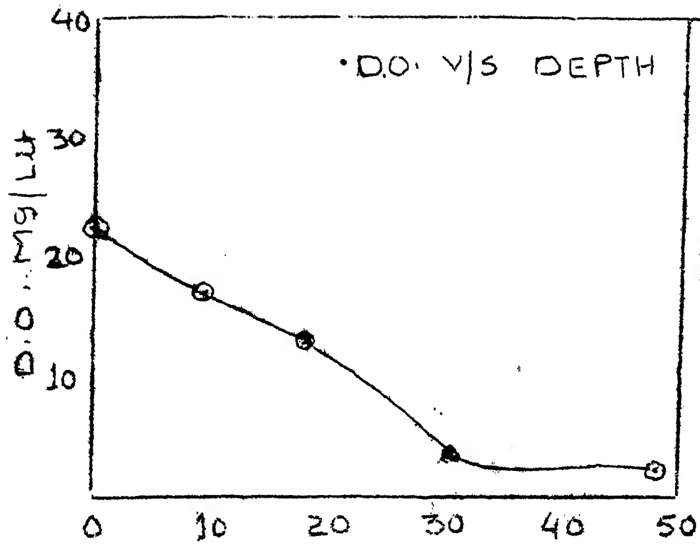
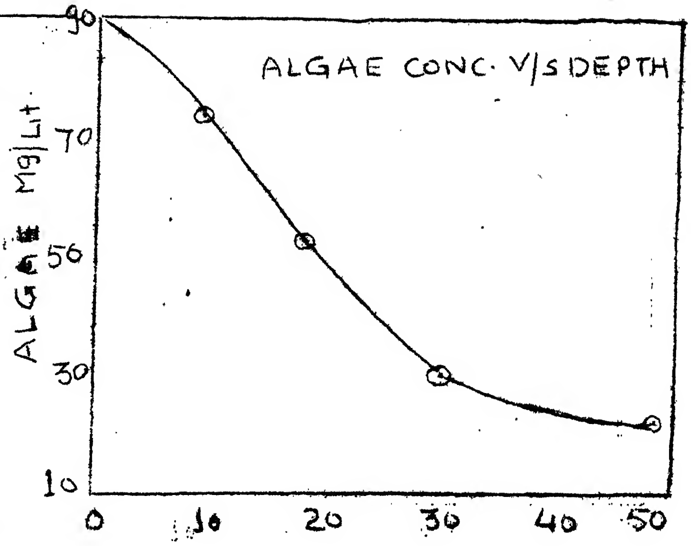
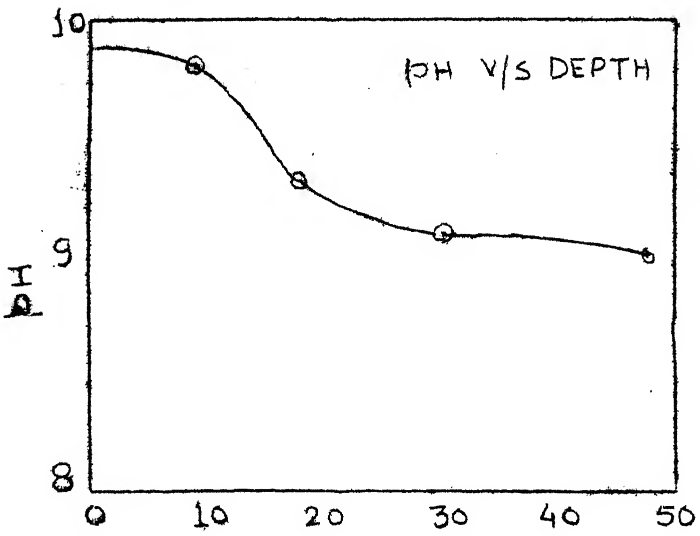
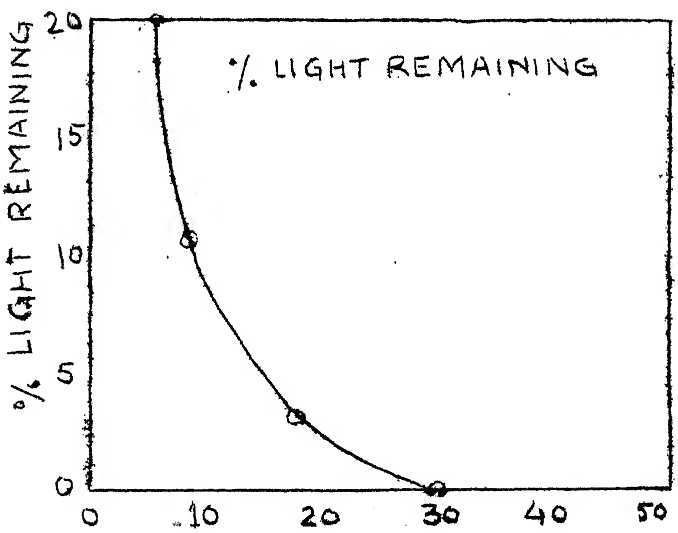


Fig. 4.3 VERTICAL DISTRIBUTION OF VARIOUS PARAMETERS AT STATION-1.


D.O. V/S DEPTH
D.O. Mg/Lit
40
30
20
10
0
10
20
30
40
50


ALGAE CONC. V/S DEPTH
ALGAE Mg/Lit
90
70
56
30
10
0
10
20
30
40
50


pH V/S DEPTH
pH
10
9
8
0
10
20
30
40
50


% LIGHT REMAINING
% LIGHT REMAINING
20
15
10
5
0
0
10
20
30
40
50

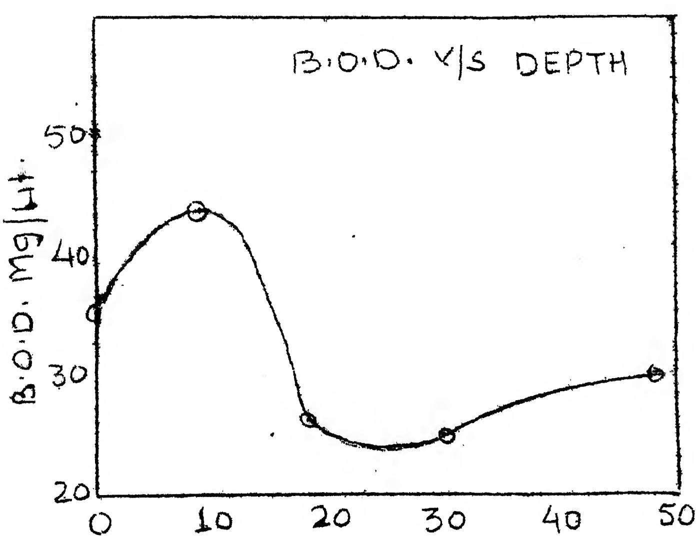

B.O.D. V/S DEPTH
B.O.D. Mg/Lit
50
40
30
20
0
10
20
30
40
50

FIG. 4.3 VERTICAL DISTRIBUTION OF VARIOUS PARAMETERS (STATION NO.6)

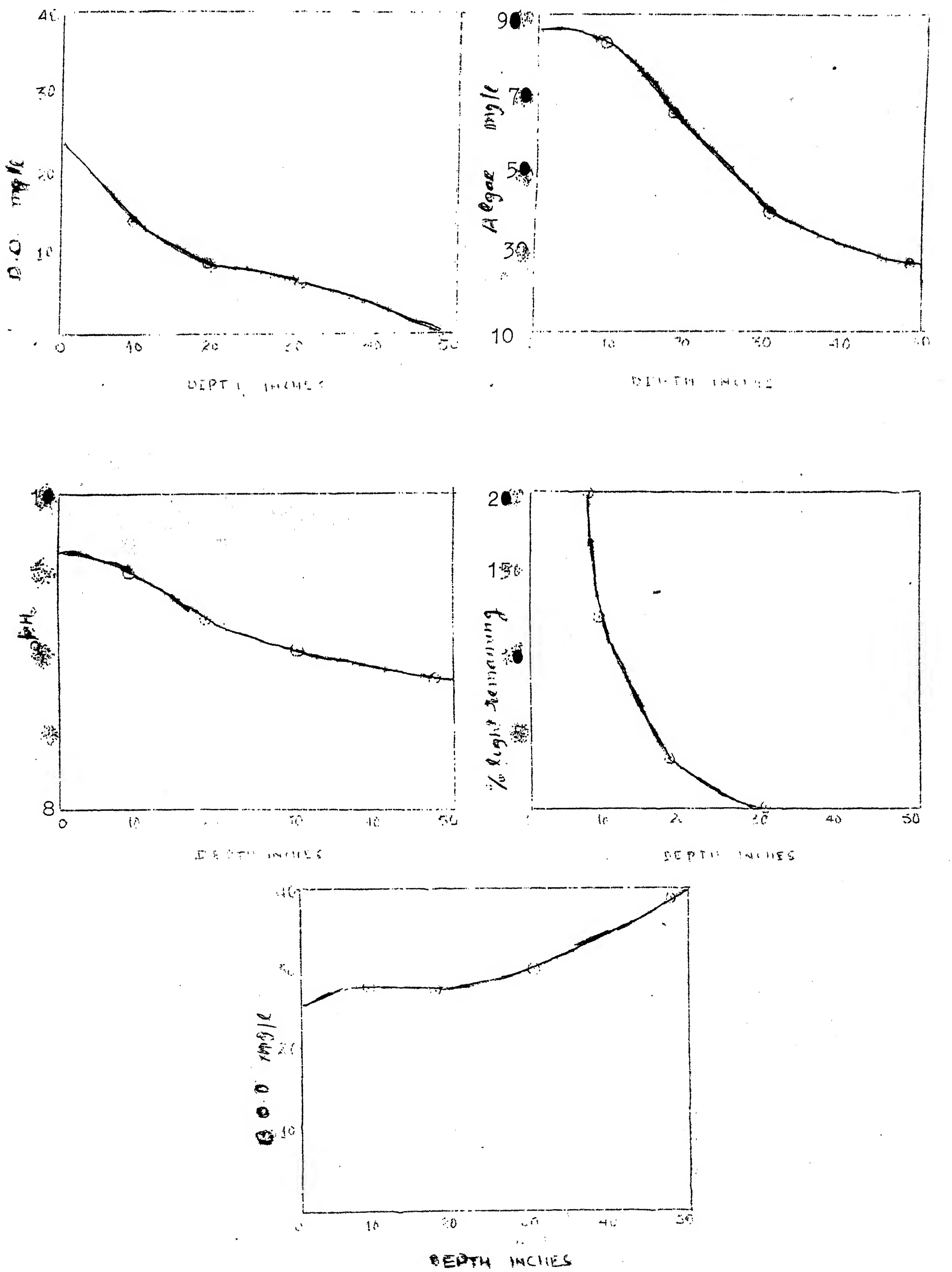


FIG 4.6 Vertical Distribution of Various Parameters

STATION NO 11

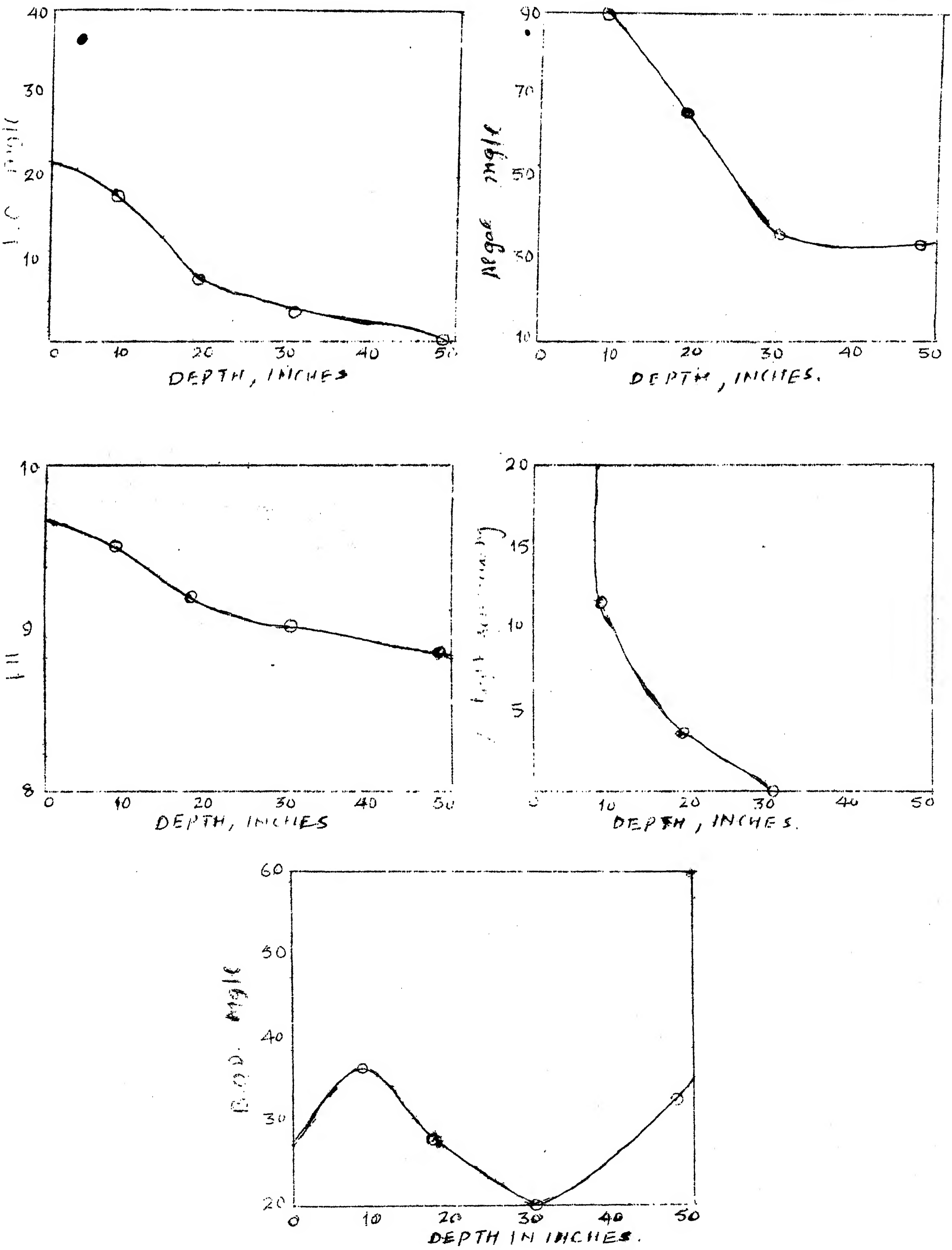
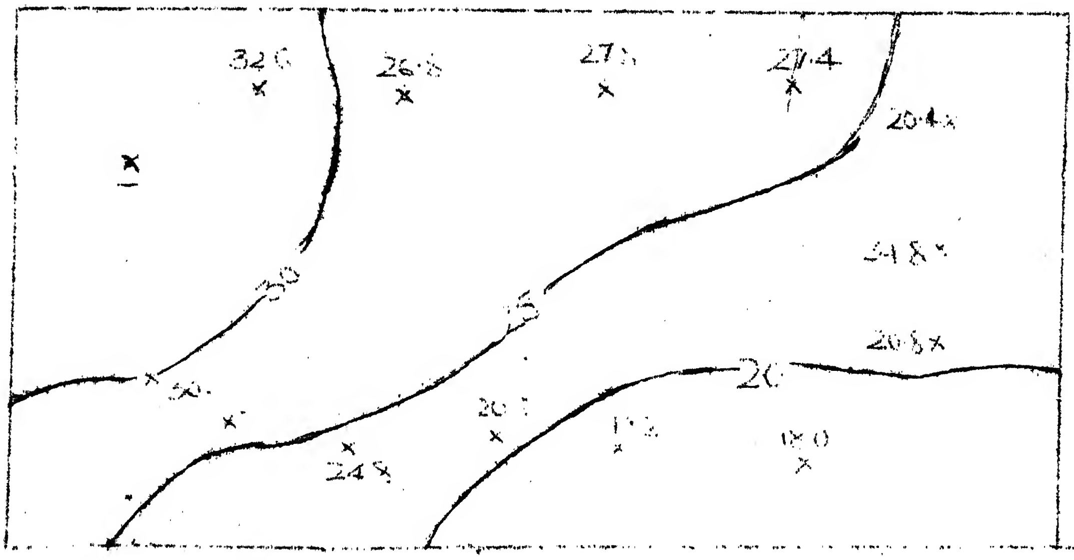
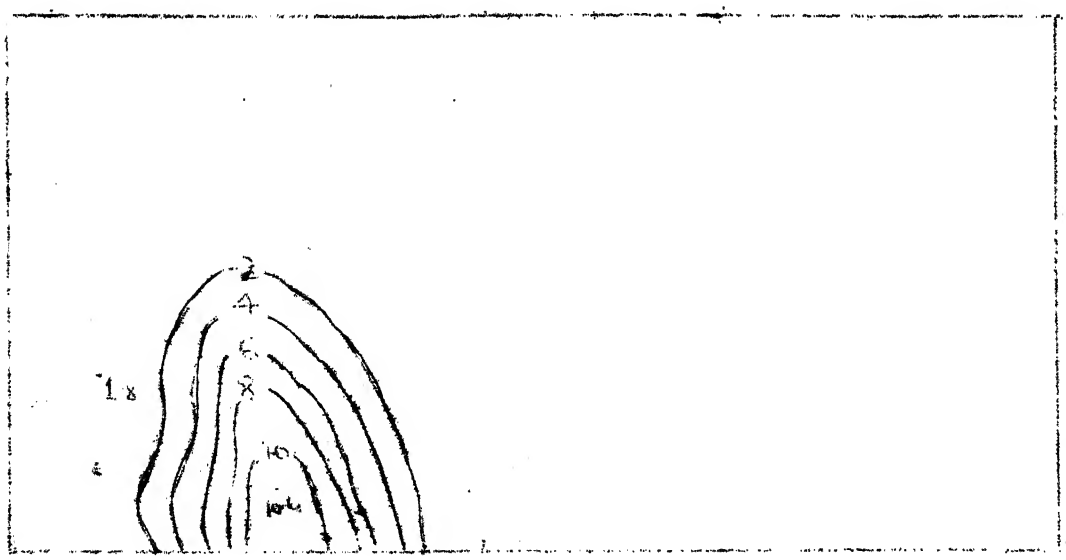


FIG. 47 D.O. CONTOURS 3" BELOW SURFACE AND AT BOTTOM.
MAY 14, 1969. TIME 1 PM.



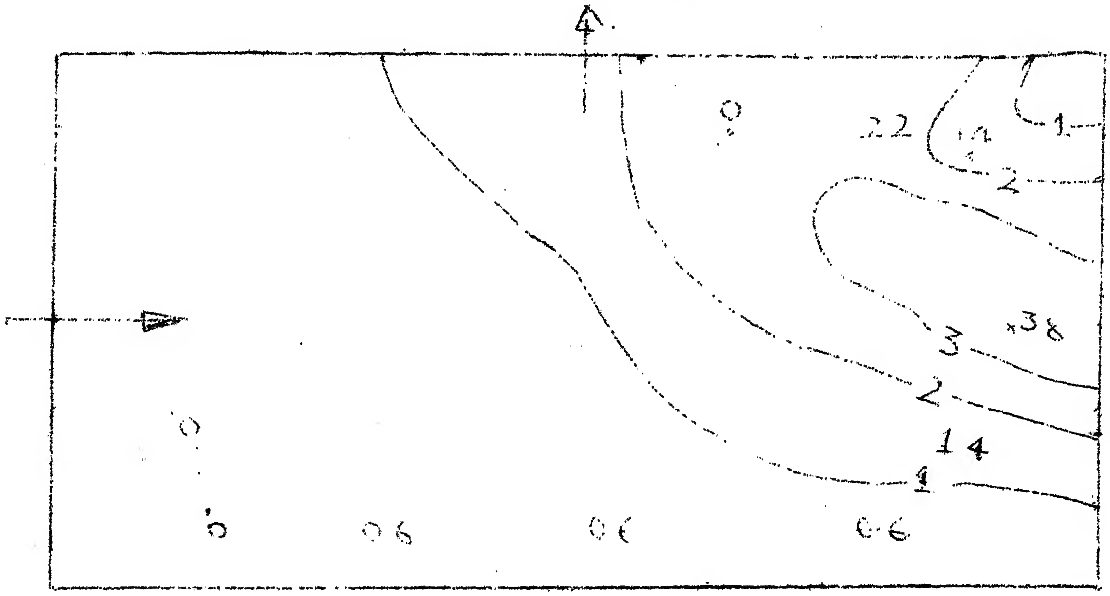
CONTOUR INTERVAL = 5 mg/l.



D.O. CONTOURS AT BOTTOM
CONTOUR INTERVAL = 2 mg/l

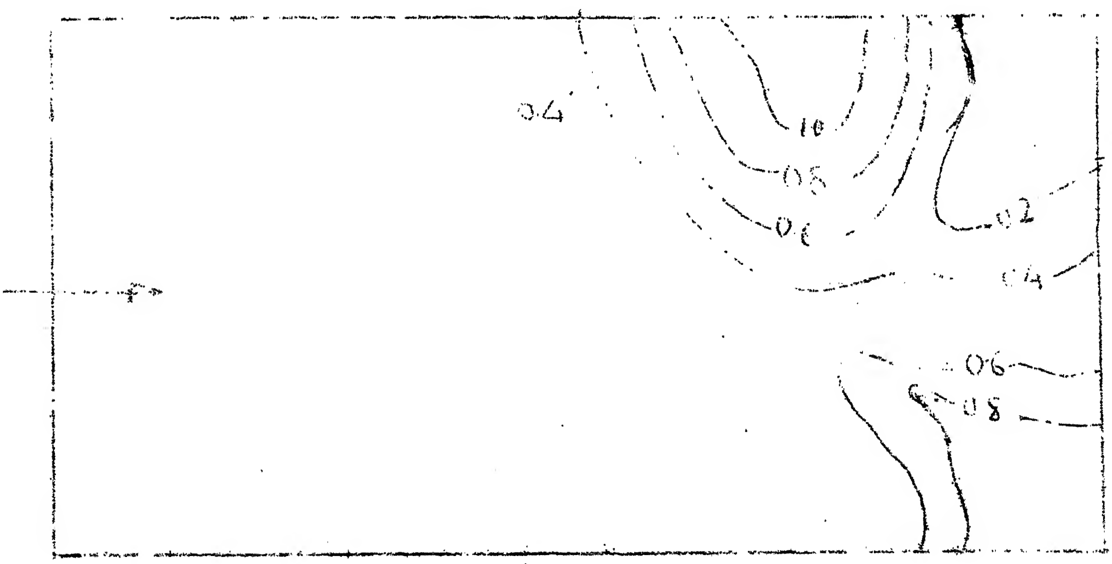
FIG 48 D.O CONTOURS, 3" BELOW SURFACE AND BOTTOM

MAY 15, 1963 6AM - 8 AM.



CONTOUR 3" BELOW SURFACE

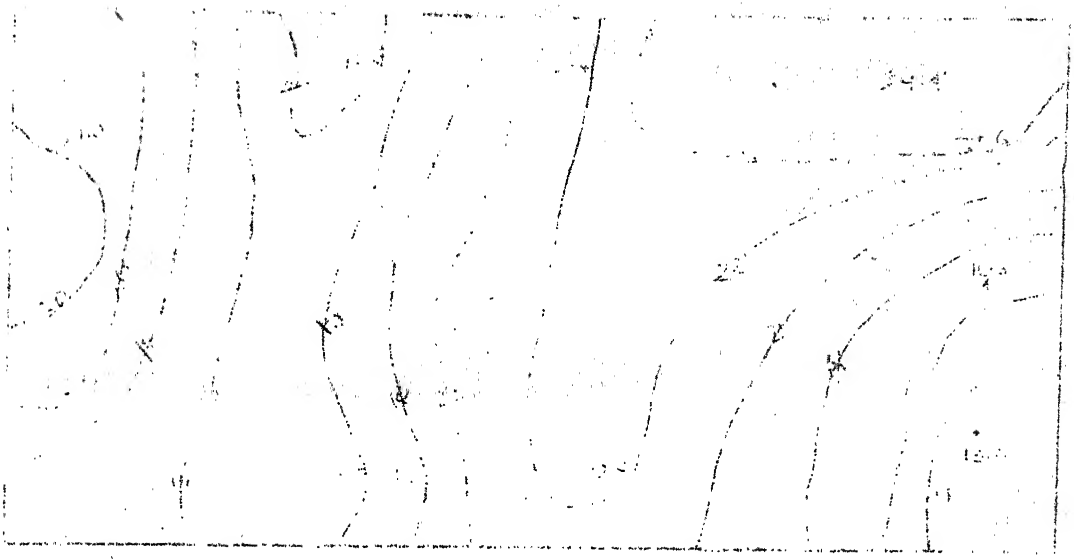
CONTOUR INTERVAL ·1mg/l.



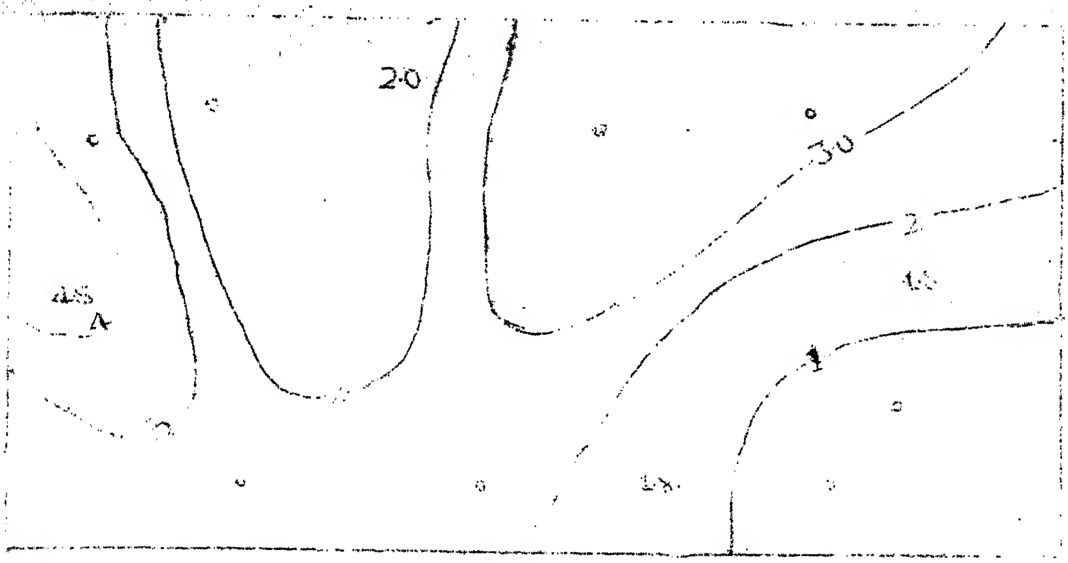
CONTOURS AT BOTTOM.

CONTOUR INTERVAL 0.2 mg/l

AND BOTTOM



contour interval, 2 mg



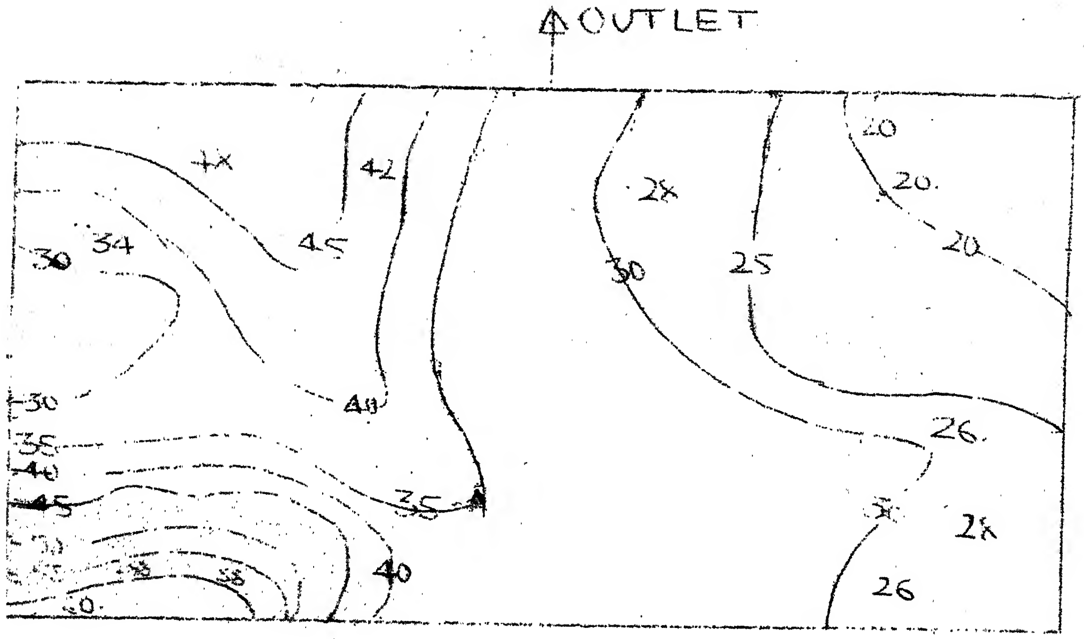
CONTOUR INTERVAL
= 1 mg/l.

CONTOURS AT BOTTOM.

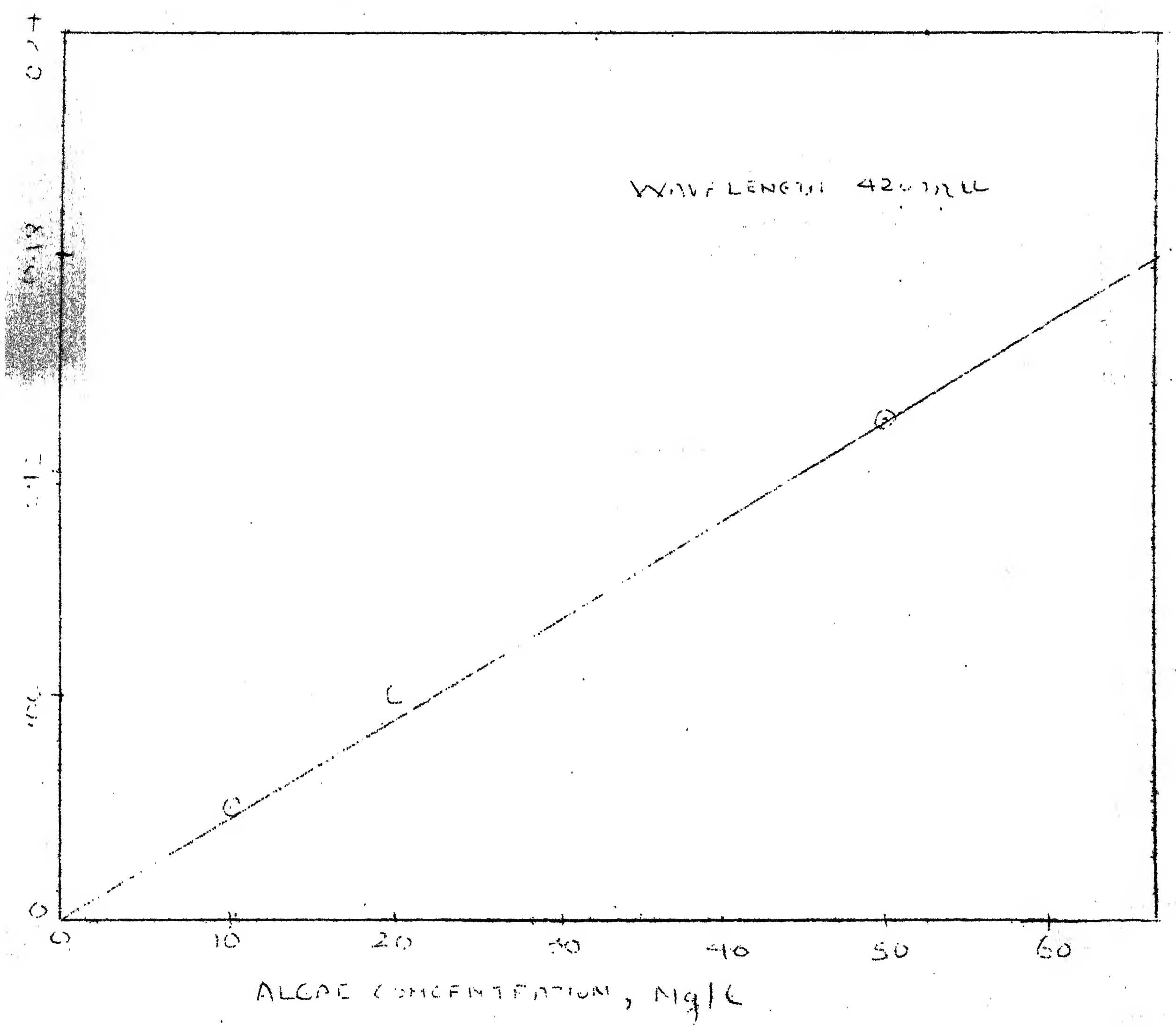
FIG 4·10

5 DAY, 20°C, B.O.D CONTOURS:-
9" BELOW SURFACE.

JUNE 11, 69.



CONTOUR INTERVAL = 5 mg/l. B.O.D.


0
10
20
30
40
50
60
ALGAE CONCENTRATION, Mg/L

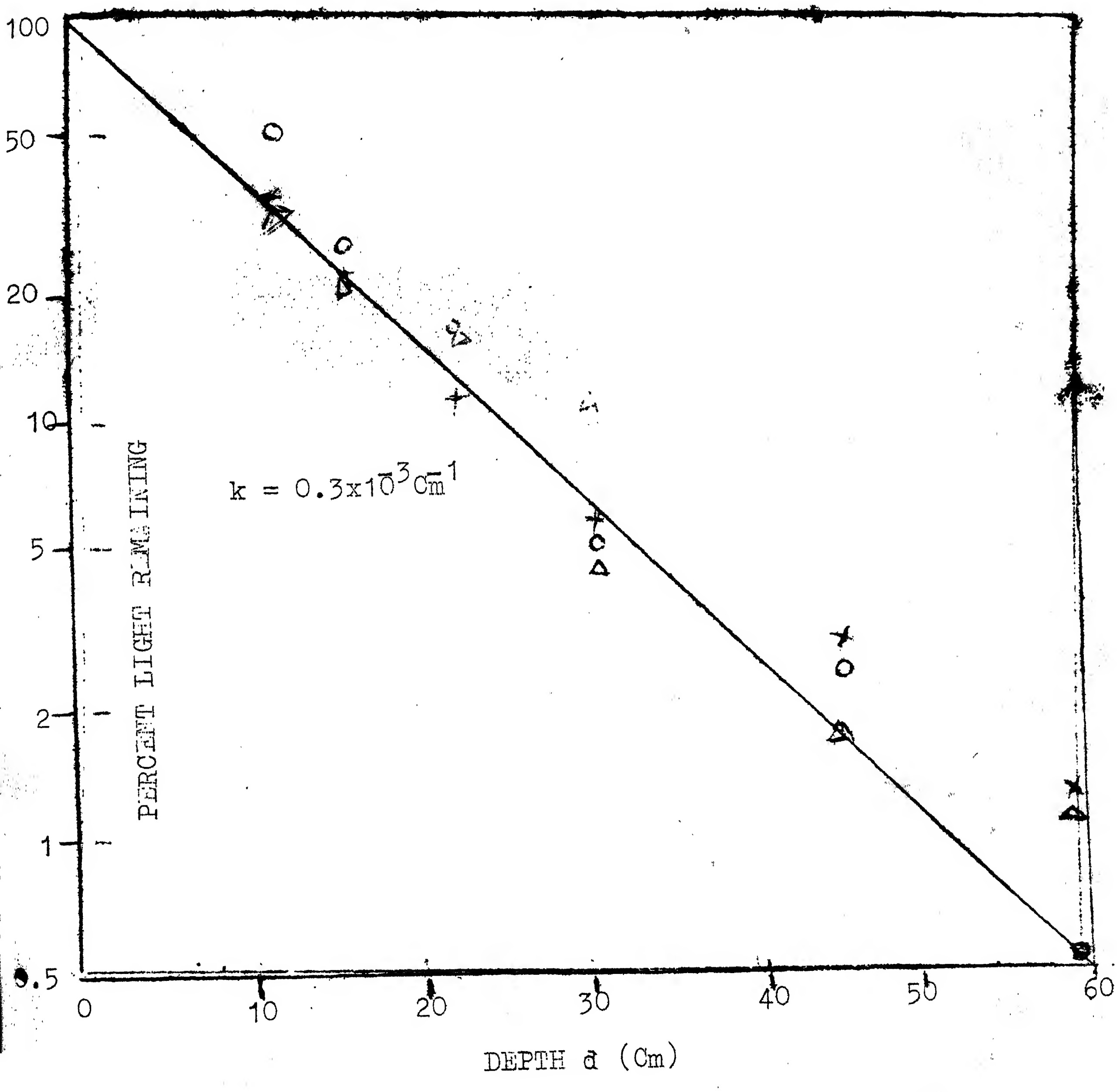


Fig.4.11 PERCENT LIGHT REMAINING vs DEPTH, 3PM

APPENDIX

METHOD CORRELATION ANALYSIS

Light intensity, concentration of algae, oxygen produced and depth of the pond are inter dependent variable parameters. A number of observations were made for these parameter at various points in the pond and an emperical relation was found out by using method given in methods of correlation analysis (28). The simultaneous equations were solved with the help of computer. The out line of the method is given below:

The regression equation was assumed to be curvilinear of cubic degree. Taking x_1, x_2, x_3 and x_4 as variable parameters.

$$X_1 = a + f_2(x_2) + f_3(x_3) + f_4(x_4)$$

Where
$$f_2(x_2) = b_2x_2 + b'_2(x_2^2) + b''_2(x_2)^3$$
$$f_3(x_3) = b_3x_3 + b'_3(x_3^2) + b''_3(x^3)$$
$$f_4(x_4) = b_4x_4 + b'_4(x_4^2) + b''_4(x_4^3)$$

or
$$X_1 = a + b_1 x_2 + b_2 x_3 + b_3 + x_4 + b_4 x_5 + b_5 x_6 + b_6 x_7 + b_7 x_8 + b_8 x_9 + b_9 x_{10}$$

Where $X_2 = x_2$ $X_3 = x_2^2$ $X_4 = x_2^3$

$X_5 = x_3$ $X_6 = x_3^2$ $X_7 = x_3^3$

$X_8 = x_4$ $X_9 = x_4^2$ $X_{10} = x_4^3$

Now

$$\Sigma(x_2^2)\ b_1 + \Sigma(x_2x_3)\ b_2 + \Sigma(x_2x_4)\ b_3 + \cdots + \Sigma(x_2x_{10})\ b_9 = \Sigma(x_1x_2)$$

$$\Sigma(x_2x_3)\ b_1 + \Sigma(x_3^2) b_2 + \Sigma(x_3x_4)\ b_3 + \cdots + \Sigma(x_3x_{10})\ b_9 = \Sigma(x_1x_3)$$

$$\Sigma(x_2x_4)\ b_1 + \Sigma(x_3x_4)\ b_2 + \Sigma(x_4^2)\ b_3 + \cdots + \Sigma(x_4x_{10})\ b_9 = \Sigma(x_1x_4)$$

$$\Sigma(x_2x_7)\ b_1 + \Sigma(x_3x_7)\ b_2 + \Sigma(x_4x_7)\ b_3 + \cdots + \Sigma(x_{10}^2)\ b_9 = \Sigma(x_1x_{10})$$

or $(x_ix_j) = (x_ix_j) - n\ M_i\ M_j$ where n is the number of sets available, i and j are integens from 1 to 10.

$$M_p = \frac{\Sigma X_p}{n} \text{ -- here p varies from 1 to 10.}$$

Now nine constents, b_1 to b_9 can be found out from above by solving these with computer.

Then $a = M_1 - b_1M_2 - b_2M_3 - b_3M_4$ ----- b_9M_{10}

The values for a, b_1 to b_9 i.e. all the coefficients are now known.

Substituting all the coefficients and respative values of X_2 to X_{10} in the equation we get the desired relations :

$$X_1 = a + b_1x_2 + b_2x_2^2 + b_3x_2^2 \times b_4x_3 + b_5x_3^2 + b_6x_3^2 + b_7x_4 + b_8x_4^2 + b_9\ x_4^3 .$$

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